A Vision for Crop Improvement and Food Security in a Changing Climate

Speakers: Alison Bentley, Charlie Messina, Geoff Morris, Tony Gathungu, and Mark Edge

Introductory Remarks: Nora Lapitan

Moderator: Angela Records

USAID FROM THE AMERICAN PEOPLE

AGRILINKS

Introductory Remarks

Nora Lapitan
Research Community of Practice Lead,
USAID Bureau for Resilience and Food Security

Today's Speakers

Alison Bentley
Director, CIMMYT's Global Wheat Program

Charlie Messina
Professor of Predictive Breeding in the Department of Horticultural Sciences, University of Florida

Geoff Morris
Associate Professor of Crop Quantitative Genomics, Colorado State University

Tony Gathungu
Global Head of Seeds2B, The Syngenta Foundation for Sustainable Agriculture (SFSA)

Mark Edge
Director of Partnerships, Seeds & Traits Business Development for LMICs, Bayer

A Vision for Crop Improvement and Food Security in a Changing Climate

Nora Lapitan
Bureau for Resilience and Food Security

USAID FROM THE AMERICAN PEOPLE

AGRILINKS

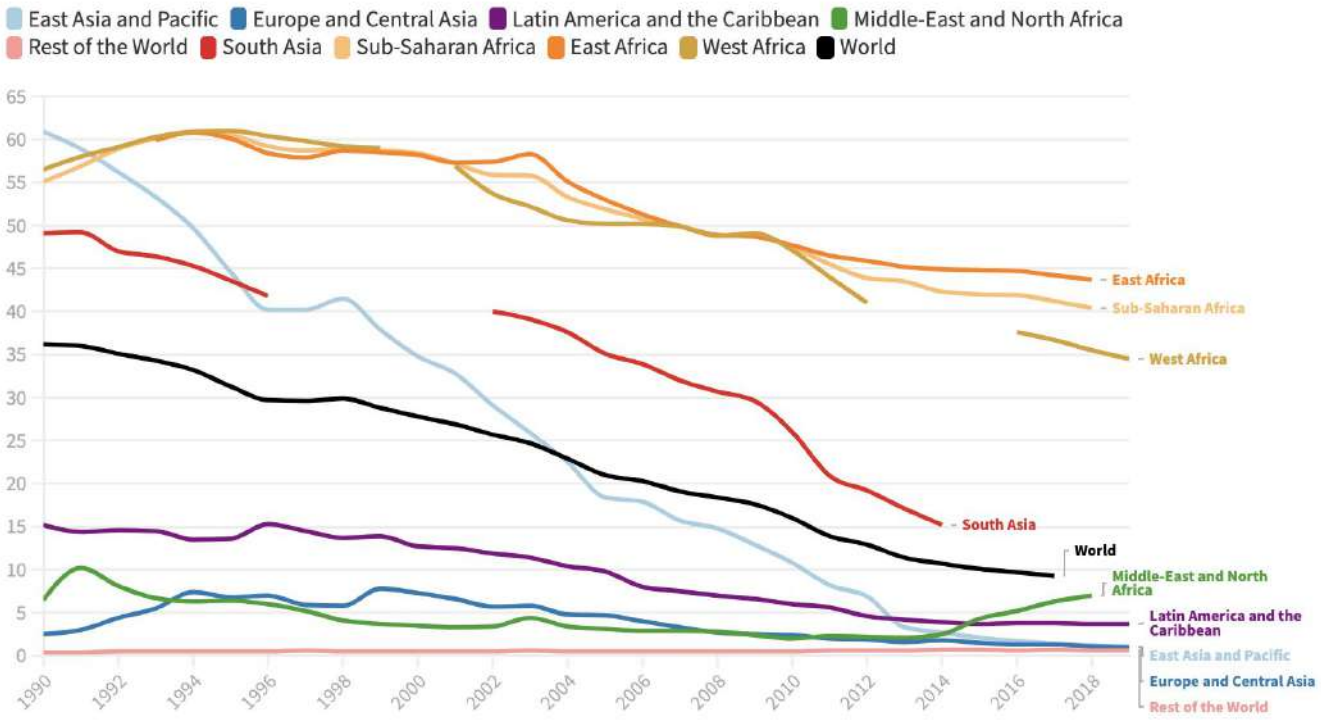
2022-2026 Global Food Security Research Strategy (to be launched in Spring 2022)

- Annotated outline for input until Feb. 11, 2021
- Three priorities to address the goal of reducing poverty and child stunting by 20%:
  - Climate change
  - Diet quality and affordability
  - Diversity, equity, and inclusion

AGRILINKS

Climate change is forecasted to increase global poverty rates

- 9.4% global extreme poverty rate (people earning $1.90 or less/day)
- Greatest concentration of poverty in SSA and South Asia
- Climate change will drive up to $132 million people to extreme poverty by 2030



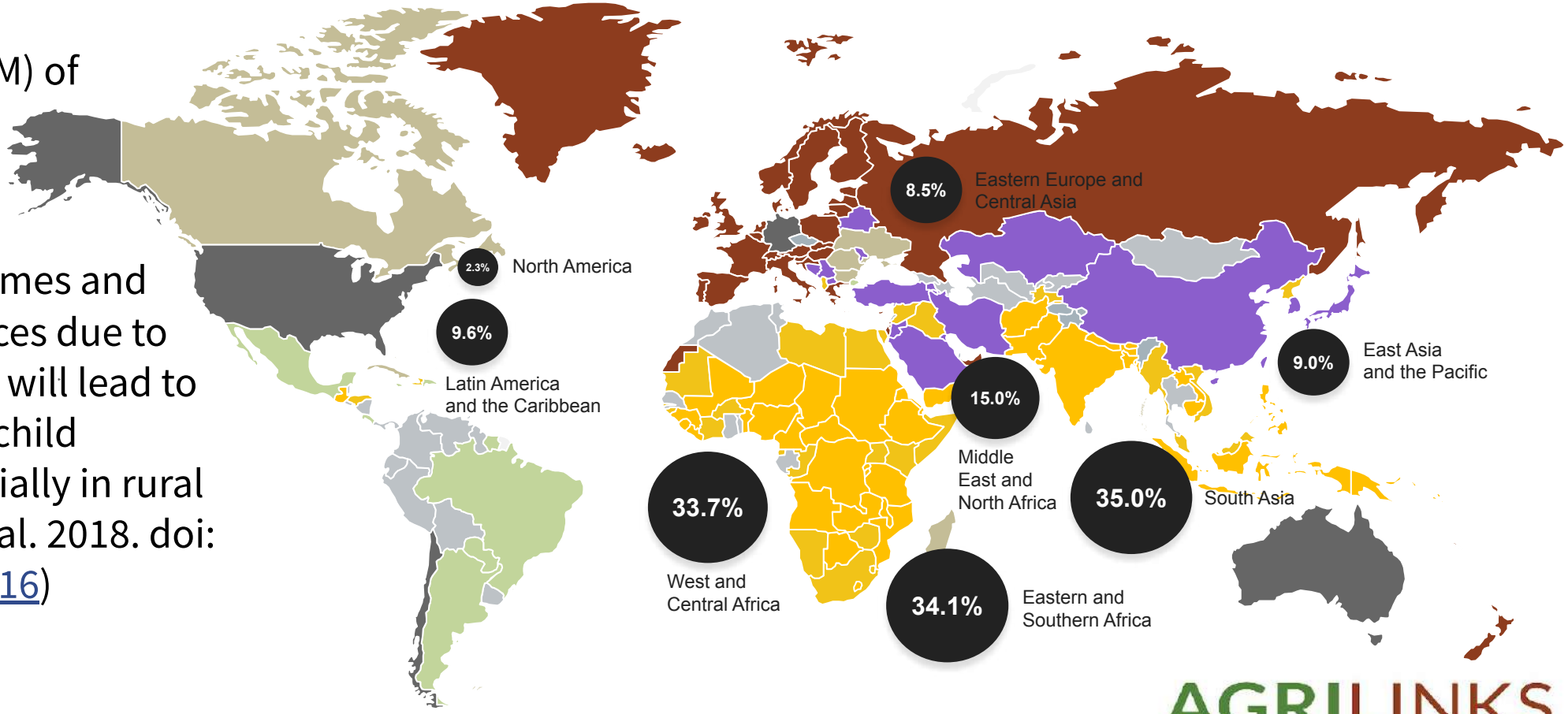
Source: PovcalNet

WORLD BANK GROUP

AGRILINKS

Prevalence of child stunting is positively correlated with extreme poverty

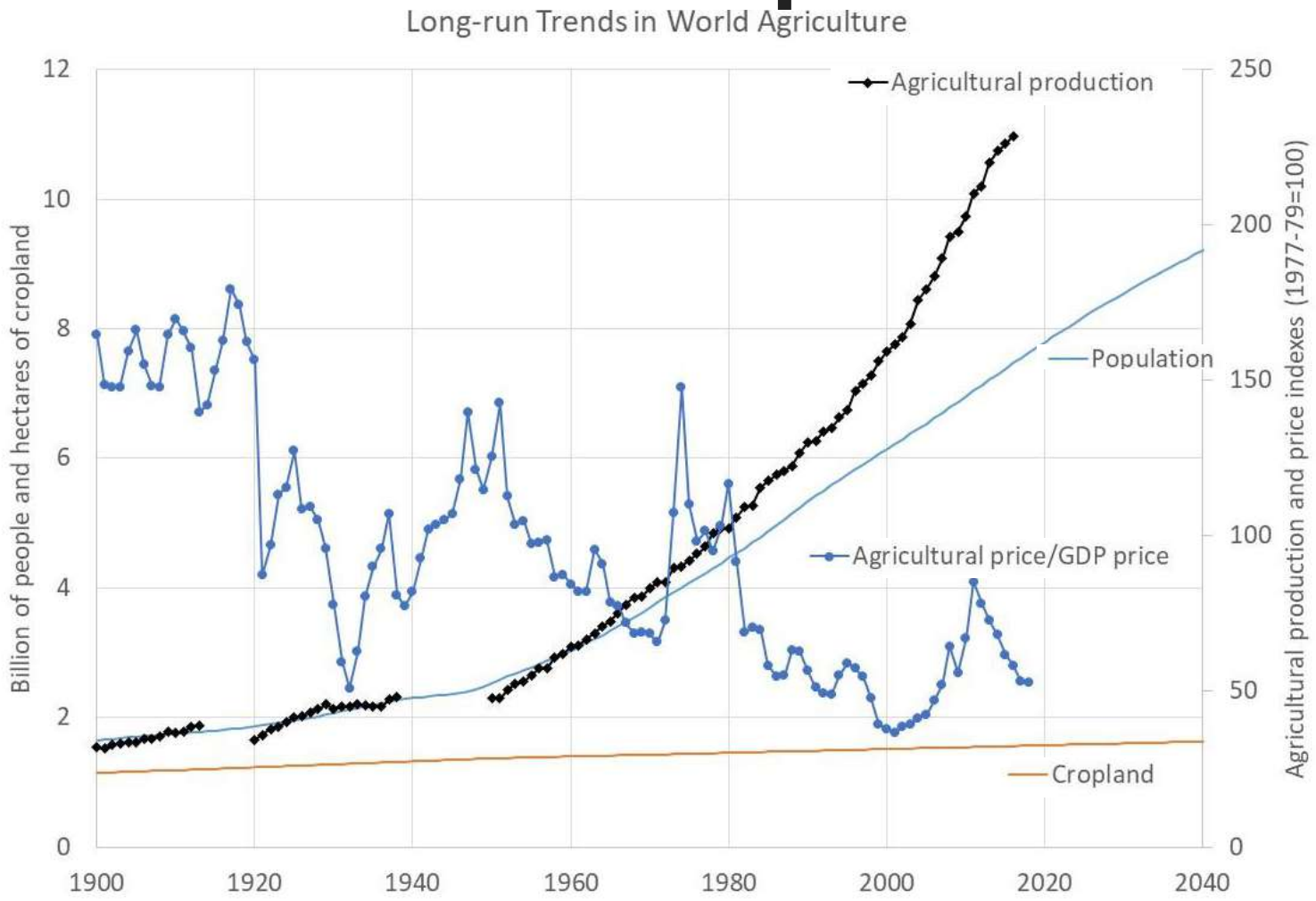
- Over 20% (149 M) of children are stunted
- Decreased incomes and higher food prices due to climate change will lead to higher rates of child stunting, especially in rural areas (Lloyd et al. 2018. doi: 10.1289/EHP2916)



Source: WHO/World Bank/UNICEF 2018

AGRILINKS

Agricultural productivity growth has made food cheaper and saved land



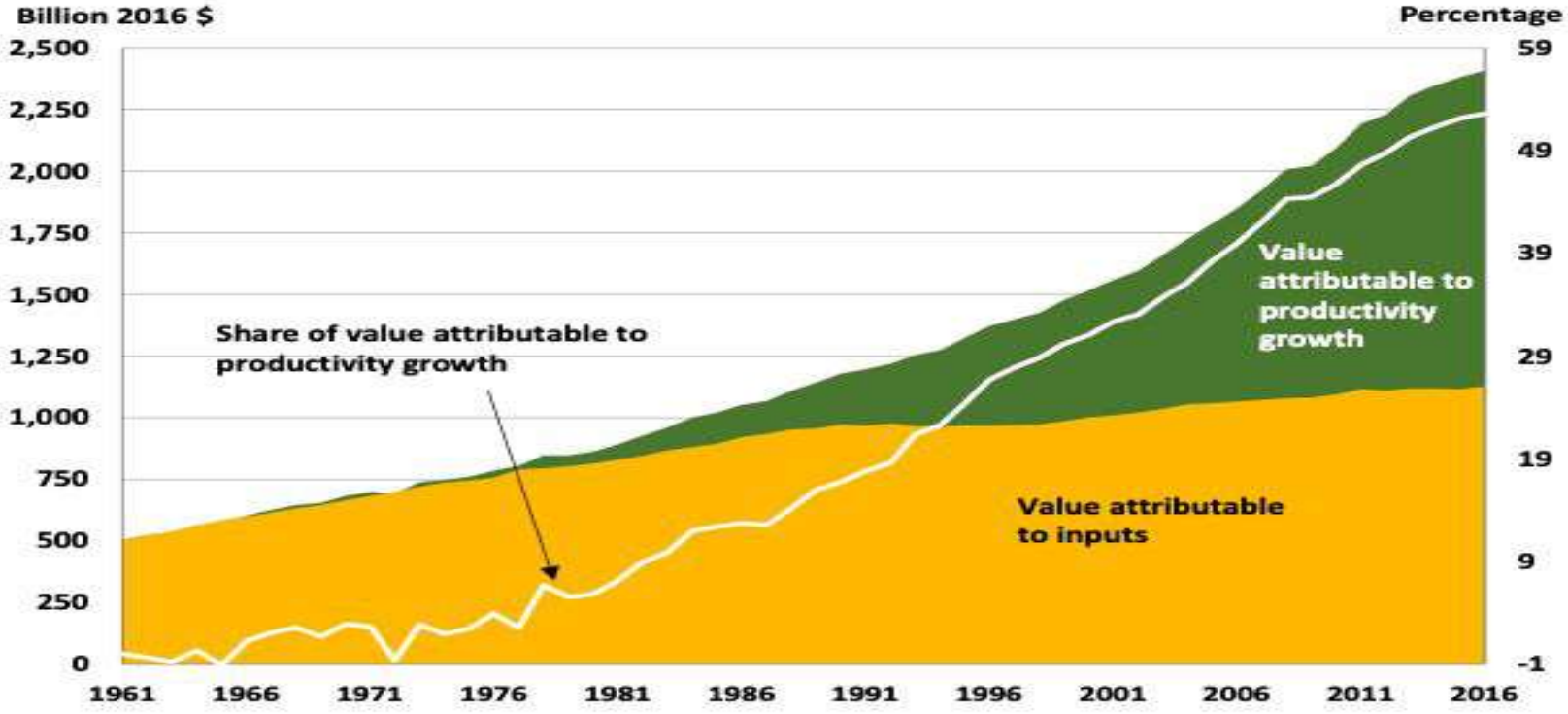
In low income countries, lower food prices is a major driver of poverty reduction and economic development

Source: Fuglie et al. (2019) *Harvesting Prosperity: Technology and Productivity Growth in Agriculture.* World Bank

AGRILINKS

Research is the Primary Driver of Agriculture Productivity Growth

Figure 13: The benefits from agricultural TFP growth in developing countries, 1961-2016



Sources: Authors' calculation based on value of production data from FAOSTAT (2020) and TFP estimates from USDA, ERS (2019).

TFP = Total factor productivity (combined productivity of all inputs)

Increase in TFP comes from cost-reducing innovations

AGRILINKS

Environmental threats to crop productivity

- Temperature Variability
- Shifting precipitation patterns
  - Drought
  - Flooding
  - Salinity
- Emergence of crop pests and pathogens
- Elevated surface CO2 concentrations



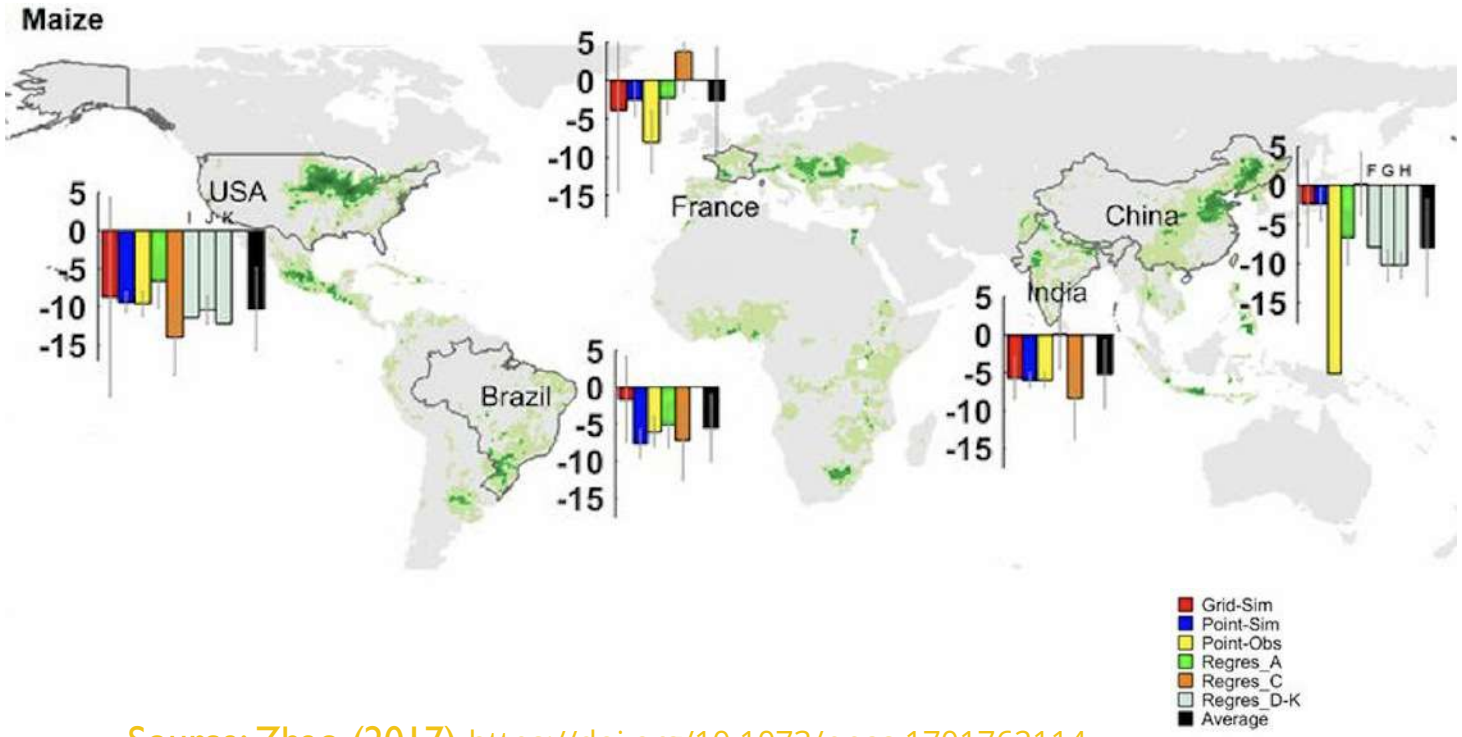


AGRILINKS

Impact of increasing temperature on crop yields

Each degree-Celsius increase in global mean temperature would, on average, **reduce global yields** of:

- Maize by 7.4%
- Wheat by 6.0%
- Rice by 3.2%
- Soybean by 3.1%.



Source: Zhao (2017) https://doi.org/10.1073/pnas.1701762114

AGRILINKS

Today’s Speakers

Alison Bentley
Applied Solutions to Safeguard Future Wheat

Charlie Messina
Breeding for Climate Change: Perspectives

Geoff Morris
How to adapt sorghum for climate change? NARS-led breeding networks and many small decisive experiments

Tony Gathungu
Climate Smart Technologies: A look through the product life cycle lens

Mark Edge
Partnership for Climate-Smart Maize in Africa: TELA Maize Project

Thank You!

AGRILINKS

Applied solutions to safeguard future wheat

Balancing production, resilience & sustainability

Alison Bentley, CIMMYT Global Wheat Program

CIMMYT MR
International Maize and Wheat Improvement Center

AGRILINKS

USAID
FROM THE AMERICAN PEOPLE

CIMMYT
International Maize and Wheat Improvement Center

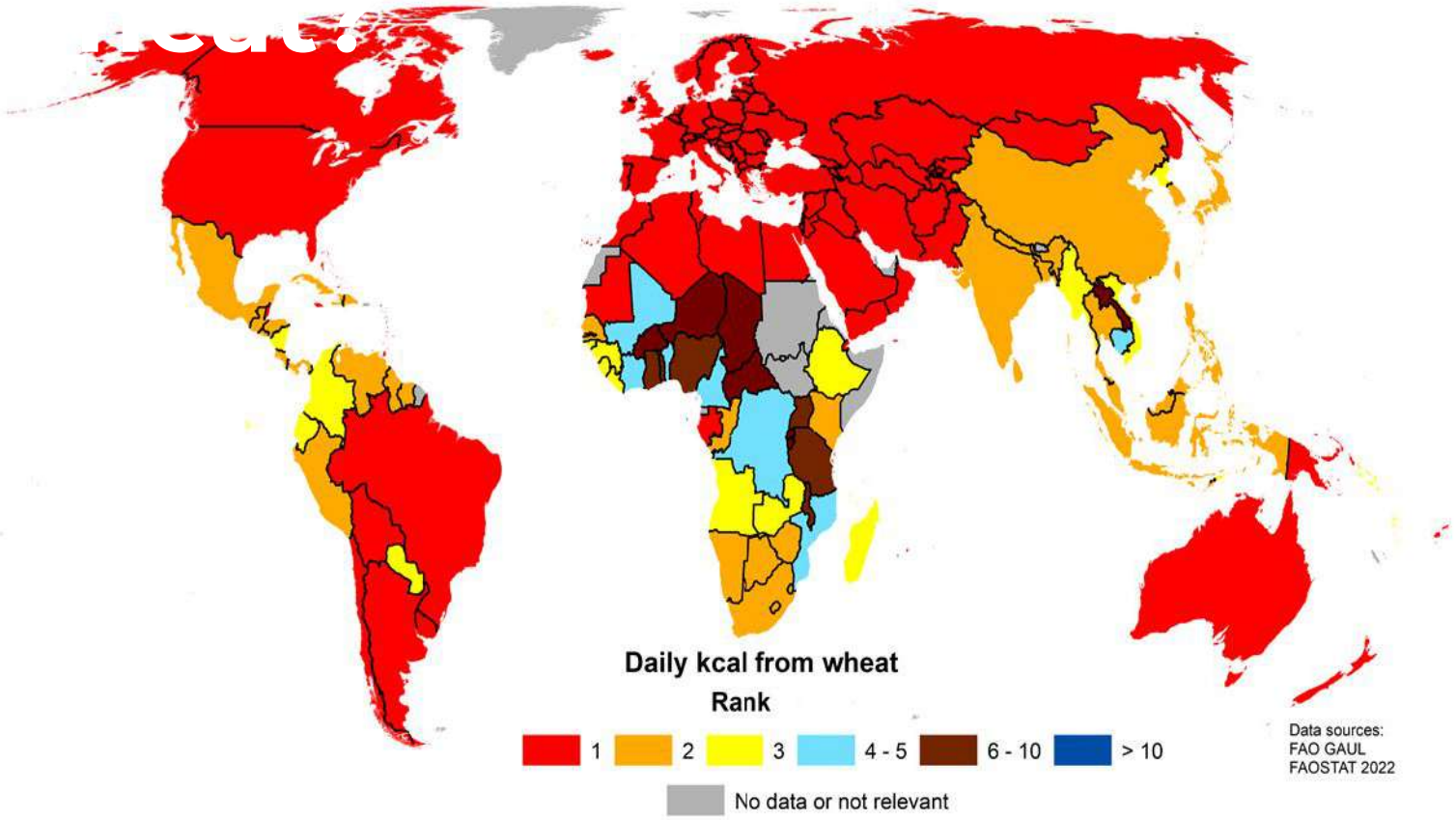
Key take-aways

- Wheat is pivotal to **alleviation of hunger**, eaten by 2.5 billion people.
- >50% of the world's wheat is grown in the Global South where projected yield declines due to climate change will **disproportionally impact production**.
- **Building resilience**, whilst maintaining productivity is crucial to safeguarding future production, underpinning food security.
- Wheat research & breeding are **accelerating improvement** and should be **integrated with system components** to achieve impact a scale.
- We require approaches to **rapidly and equitably accumulate and deploy** science innovations to smallholder farmers in the Global South.

AGRILINKS

CIMMYT
International Maize and Wheat Improvement Center

Alleviating hunger

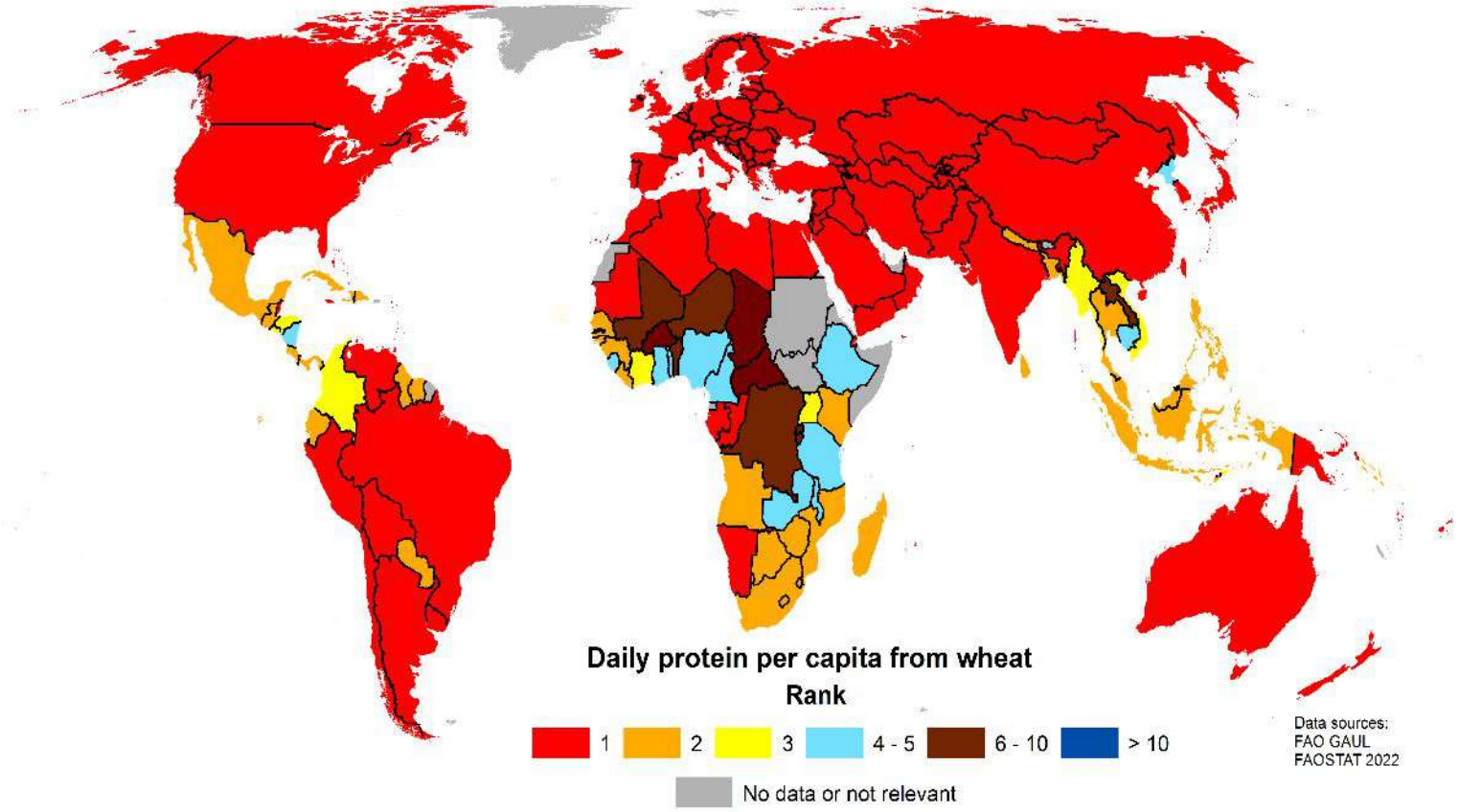


AGRILINKS

Maps produced by Kai Sonder (CIMMYT)

CIMMYT
International Maize and Wheat Improvement Center

Alleviating hunger



Read our latest blog:
https://www.cimmyt.org/blogs/fruits-and-vegetables-are-essential-but-there-are-three-reasons-why-it-takes-cereals-to-feed-the-world/

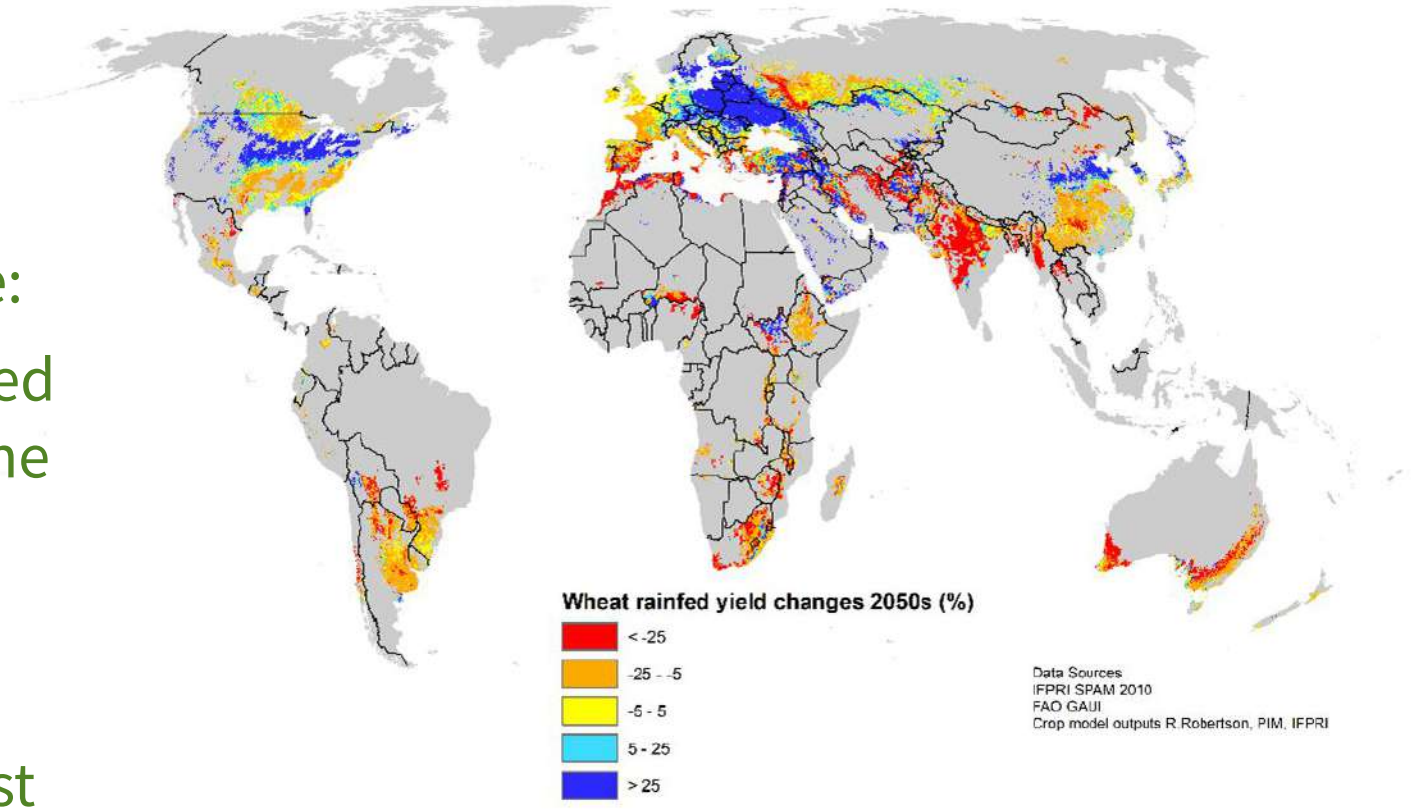
AGRILINKS

Maps produced by Kai Sonder (CIMMYT)

CIMMYT
International Maize and Wheat Improvement Center

Unequal impacts

- Patterns of global wheat production potential will change:
  - A large proportion of predicted yield decrease will occur in the Global South.
  - Projections highlight regions where climate impacts on wheat production are forecast to be greatest, allowing targeting of short, medium and long-term actions.

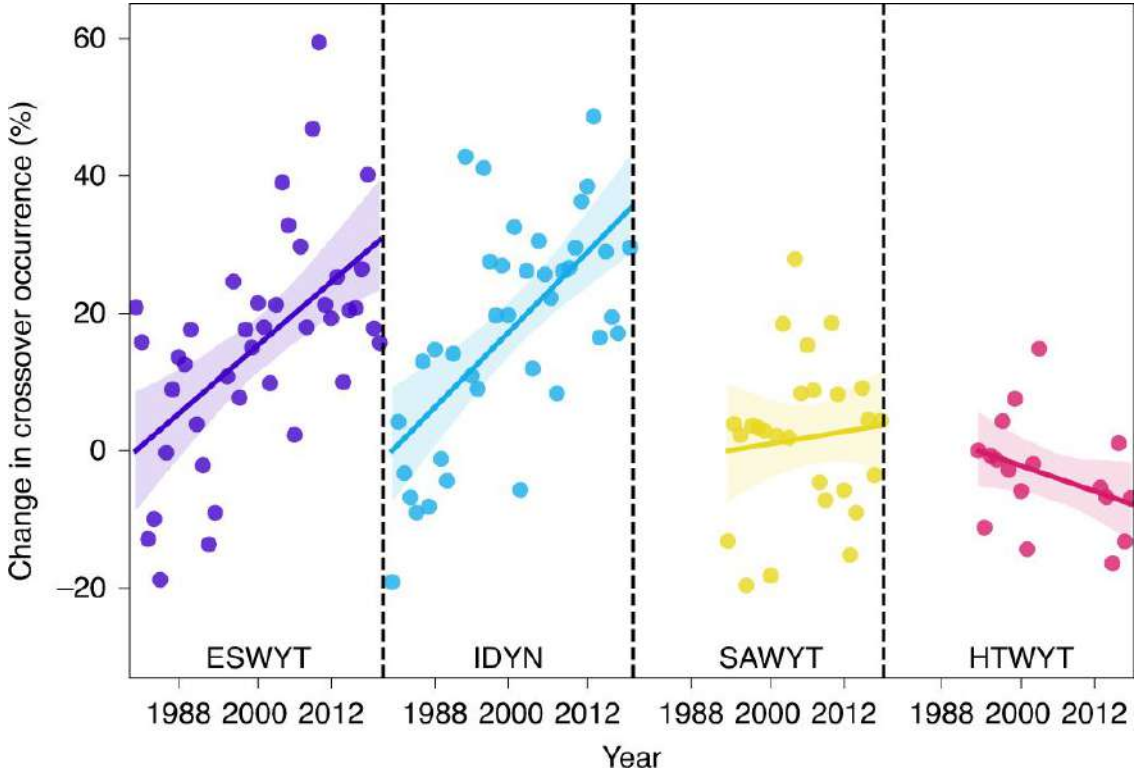


AGRILINKS

Maps produced by Kai Sonder (CIMMYT)

CIMMYT
International Maize and Wheat Improvement Center

Building resilience



From: Xiong *et al.* (2021) *Nature Plants*
https://doi.org/10.1038/s41477-021-00988-w

AGRILINKS

CIMMYT
International Maize and Wheat Improvement Center

Accelerating improvement



Accelerating Genetic Gains in Maize and Wheat

Accelerated population improvement & trait introgression




Heat and Drought Wheat Improvement Consortium

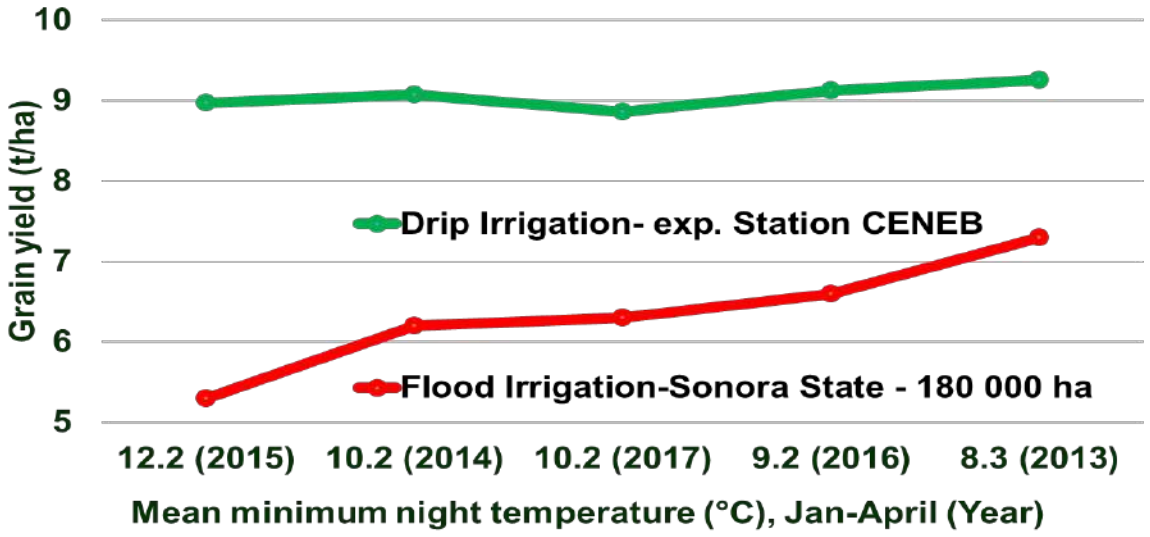
Pre-breeding and trait discovery for climate adaptation traits

AGRILINKS

CIMMYT
International Maize and Wheat Improvement Center

Integrated systems

- Heat mitigation through management
  - E.g. providing buffering yield across temperatures.



AGRILINKS

Data: Suchismita Mondal (CIMMYT)

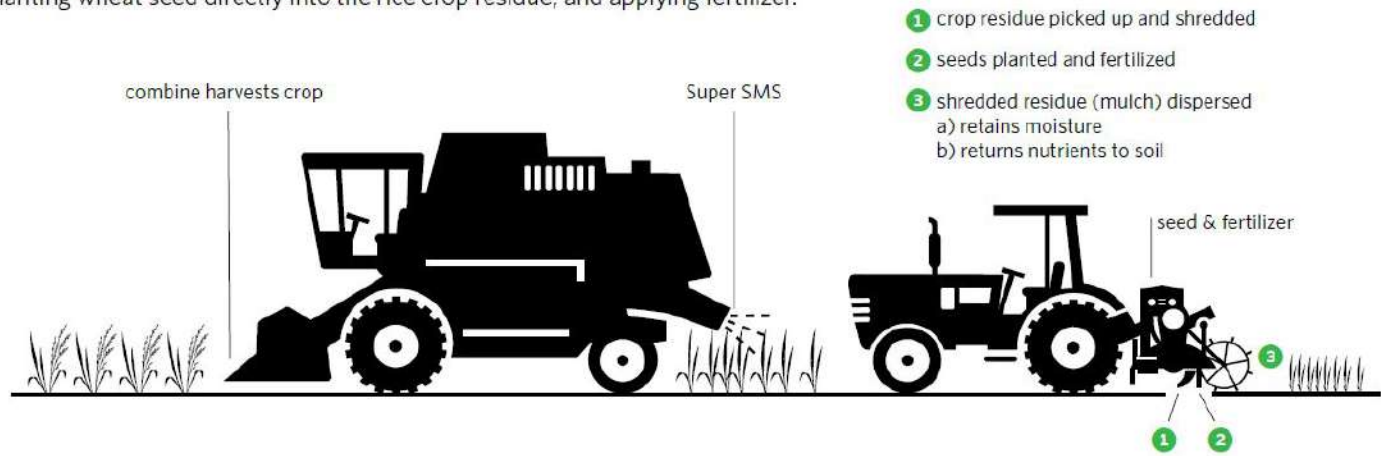
CIMMYT
International Maize and Wheat Improvement Center

Integrated systems

Optimizing varieties, cropping systems and on-farm mechanization.

CSISA

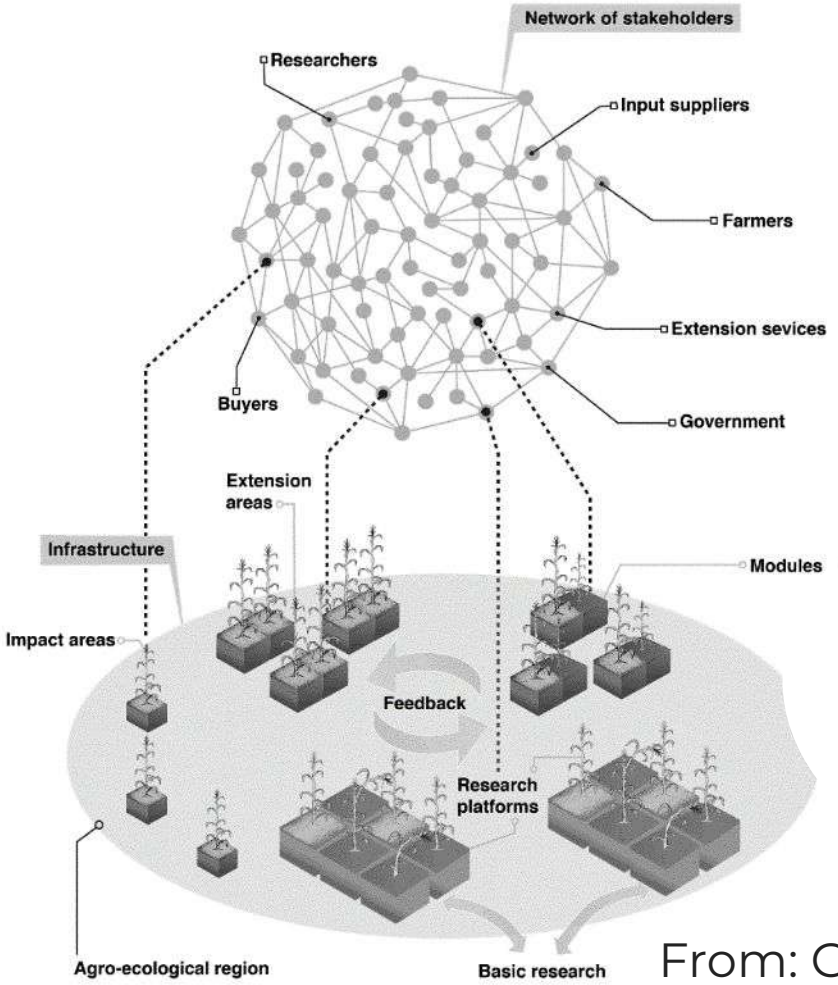
Happy Seeder rice residue management system.
A combine is fitted with a Super Straw Management System (SMS) so that rice residue is spread evenly across the field during harvest. A Happy Seeder follows, planting wheat seed directly into the rice crop residue, and applying fertilizer.

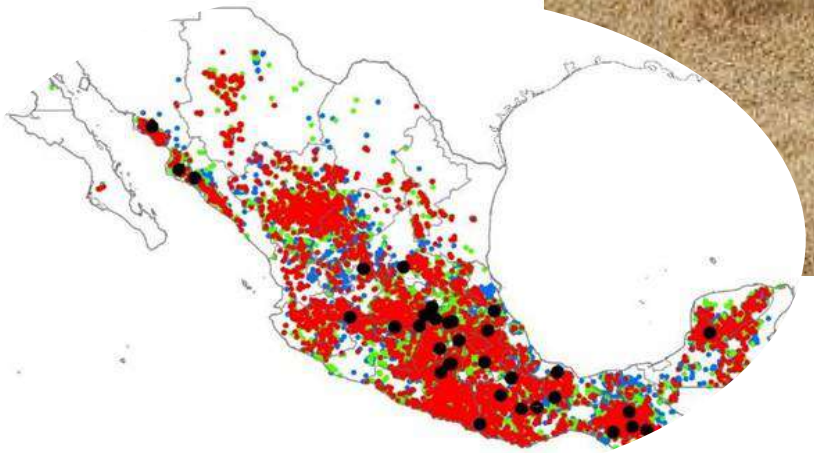


AGRILINKS

CIMMYT
International Maize and Wheat Improvement Center

Equitably accumulating & deploying innovations





AGRILINKS

From: Gardeazabal et al. (2021) https://doi.org/10.1080/14778238.2021.1884010

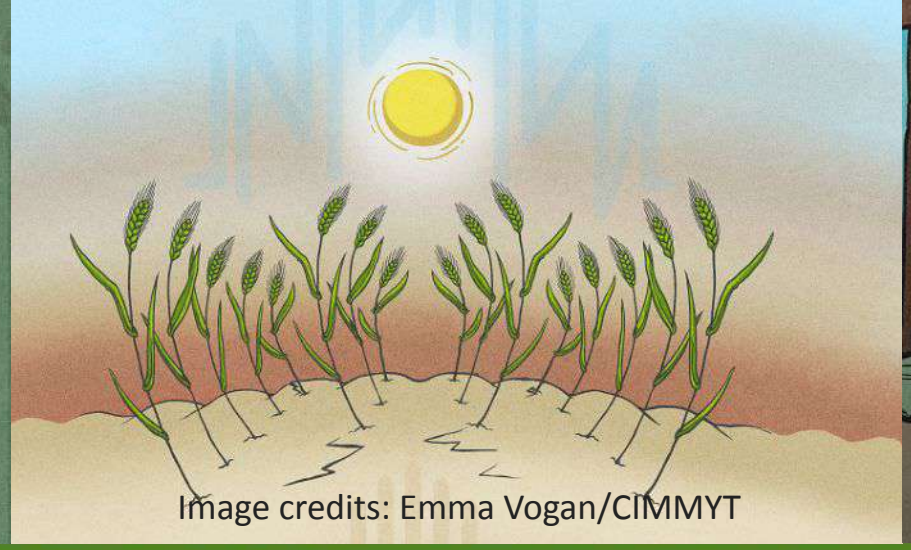


Image credits: Emma Vogan/CIMMYT

CIMMYT
International Maize and Wheat Improvement Center

Thank You

Find out more about the CIMMYT Global Wheat Program, our donors & partners:
https://www.cimmyt.org/work/wheat-research/

AGRILINKS

Breeding for Climate Change

Perspectives

Charlie Messina, PhD | Professor Horticultural Sciences University of Florida

UF IFAS
UNIVERSITY of FLORIDA

TOP TAKE-AWAYS

1. ## Framework for Breeding for Climate Change is lacking

Scientists are generating partial views from environment challenges, operations & logistics, adaptive traits, and other views but a comprehensive framework is lacking

2. ## Many journeys will be required to adapt to Climate Change

Adaptation is a journey and each geography and community will define its own. During this journey we need to create and deliver products, not too fast and not too slow. Depending on GxE, breeding for 2100 climates may be detrimental to achieve 2025+ goals

3. ## Breeding technologies demonstrated for adapting crops to stress conditions

The integrated use of precision phenotyping, managed stress environments, crop models, genomic prediction, and wide area on farm evaluations led to the successful development of AQUAmax(R) drought tolerant maize. This approach was replicated over time and geographies building a foundation for adaption of crops to Climate Change

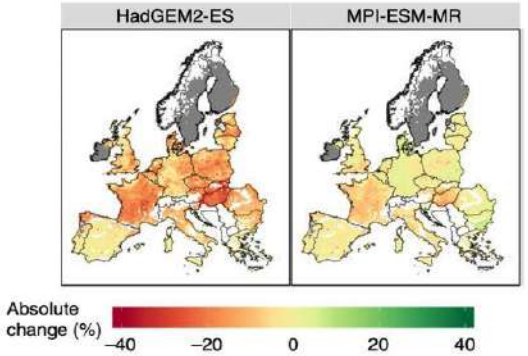
4. ## Success

We can succeed by creating and agreeing on a framework, building on successful breeding technologies and approaches, and changing consuming behaviors

Approaches to breeding for climate change

Environmental Challenge

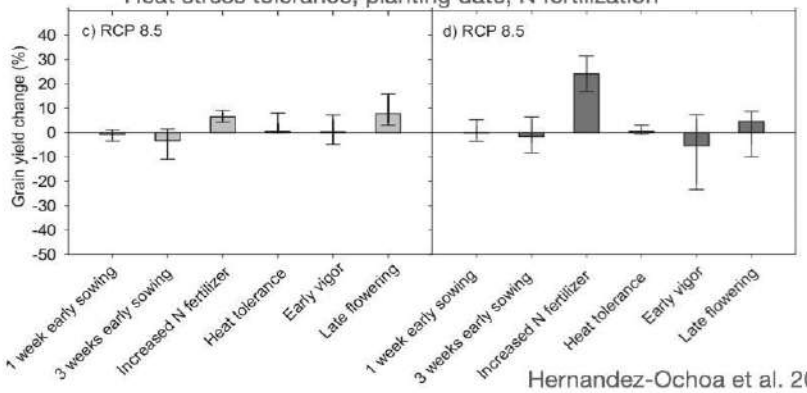
Drought underpin yield loses under climate change scenarios



Weber et al.

Crop and management design

Heat stress tolerance, planting date, N fertilization



Hernandez-Ochoa et al. 2019

Quantitative Genetics (GxE)

Nacent research to bring awareness of GxE related to Climate Change

nature plants — LETTERS

https://doi.org/10.1038/s41477-021-00988-w

Check for updates

Increased ranking change in wheat breeding under climate change

Wei Xiong[1,2], Matthew P. Reynolds[3], Jose Crossa[4], Urs Schulthess[1,2], Kai Sonder[5],

Breeding operations

Selections today may not be suitable for future climates

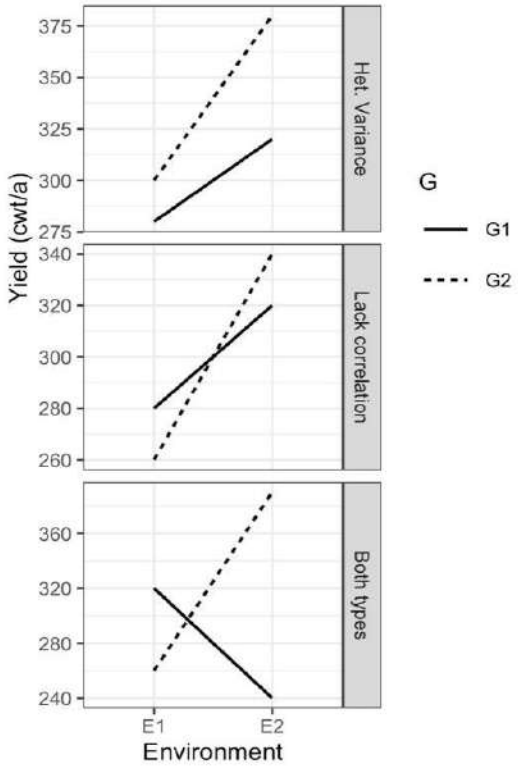
LETTERS — nature climate change

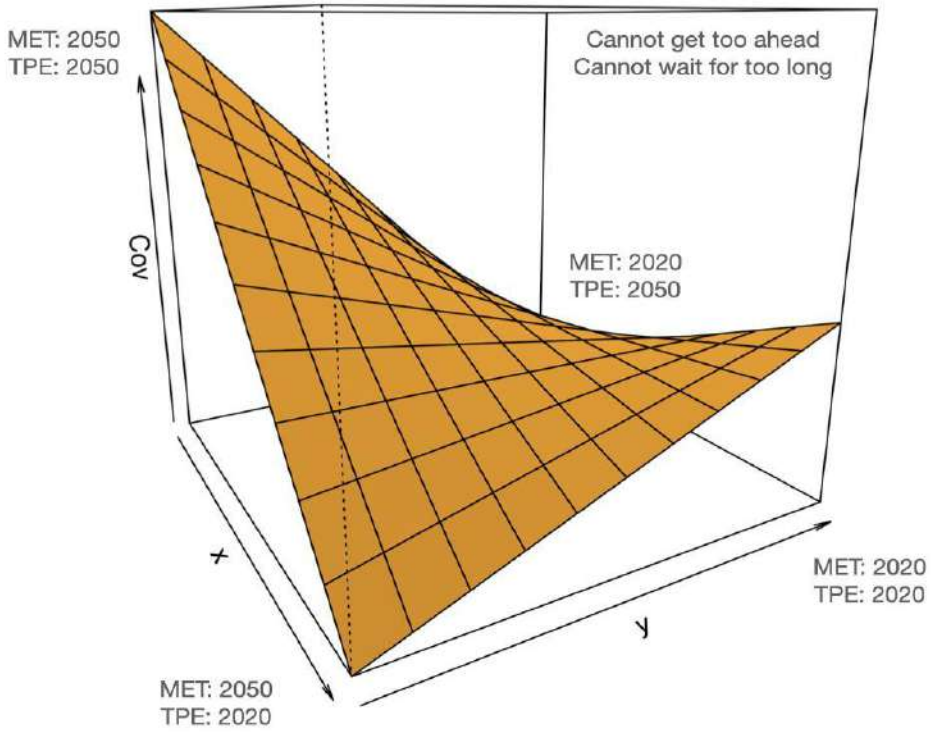
PUBLISHED ONLINE: 20 JUNE 2016 | DOI: 10.1038/NCLIMATE3061

Current warming will reduce yields unless maize breeding and seed systems adapt immediately

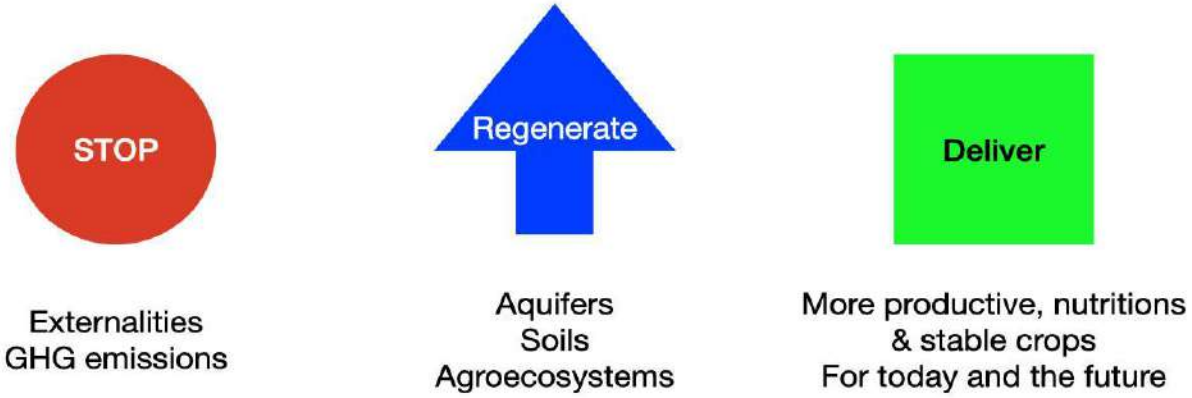
A. J. Challinor[1,2*], A.-K. Koehler[1], J. Ramirez-Villegas[1,2], S. Whitfield[3] and B. Das[4]

Genotype x environment interactions complicate selection



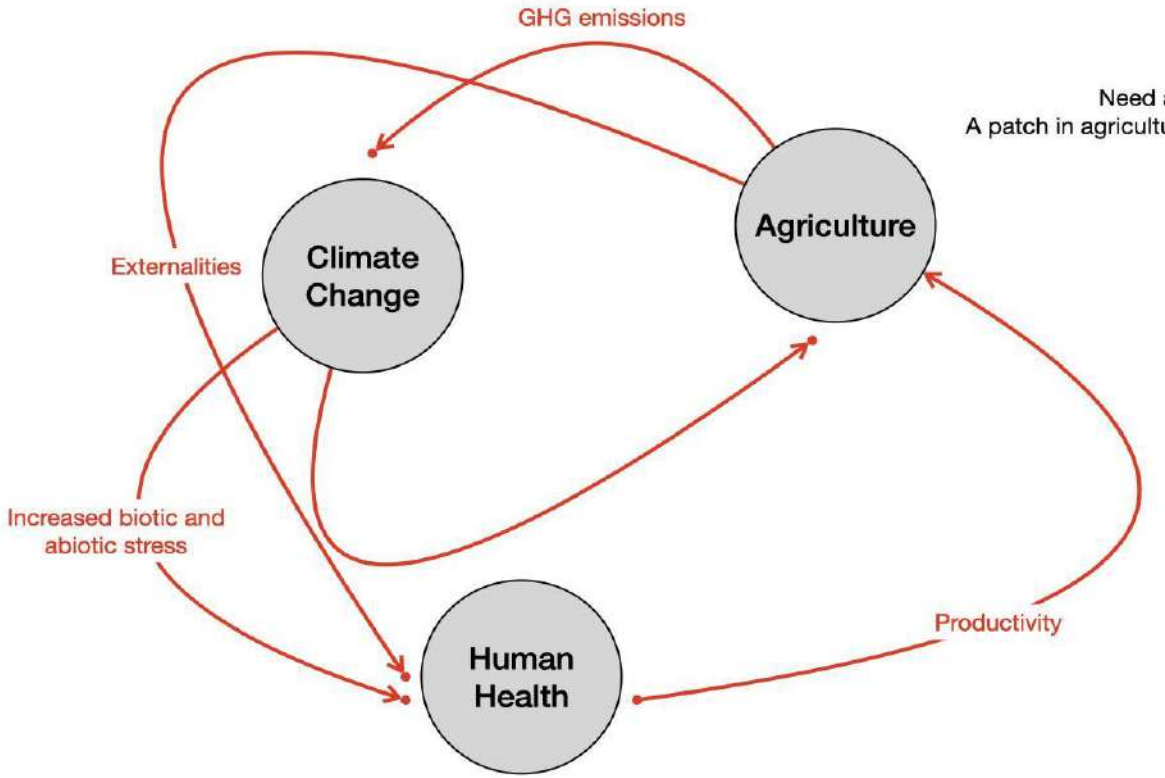


Framework core objectives



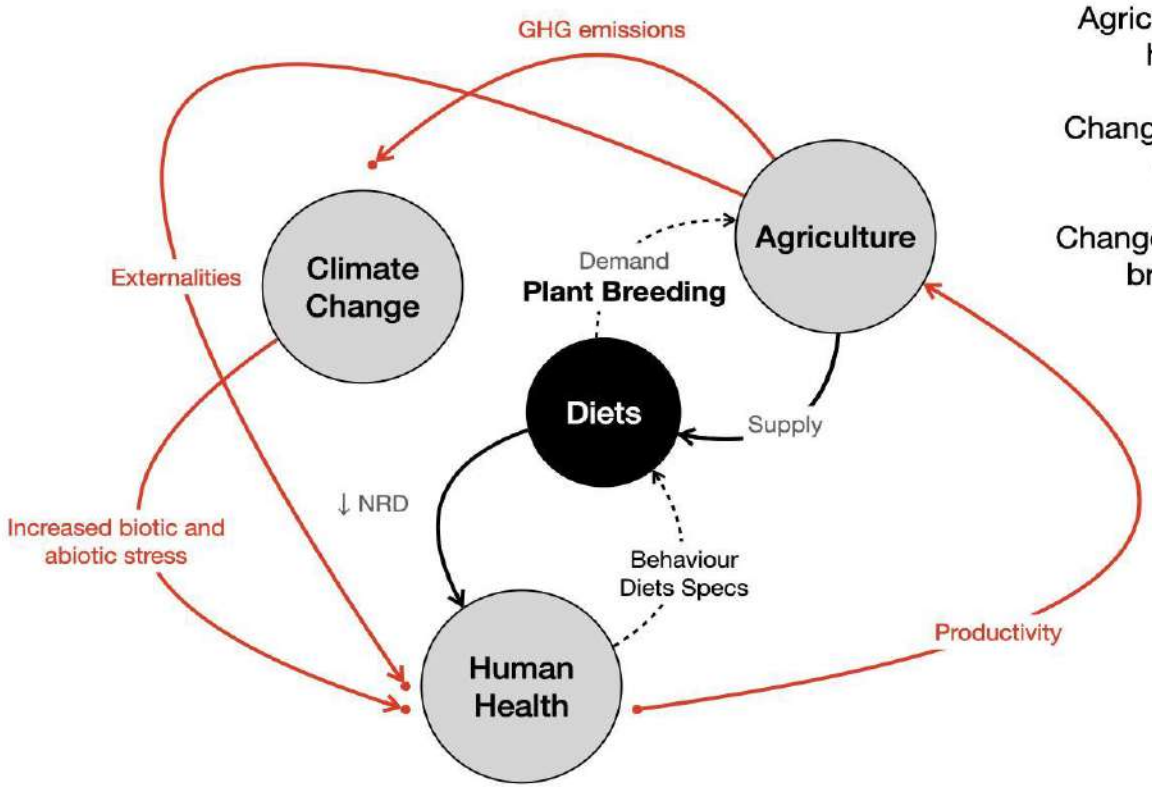
Circularity in Agriculture

See MacArthur Foundation



Need a systems view
A patch in agriculture is not a feasible solution

Human Health, Climate Change and Agriculture connected through Diets

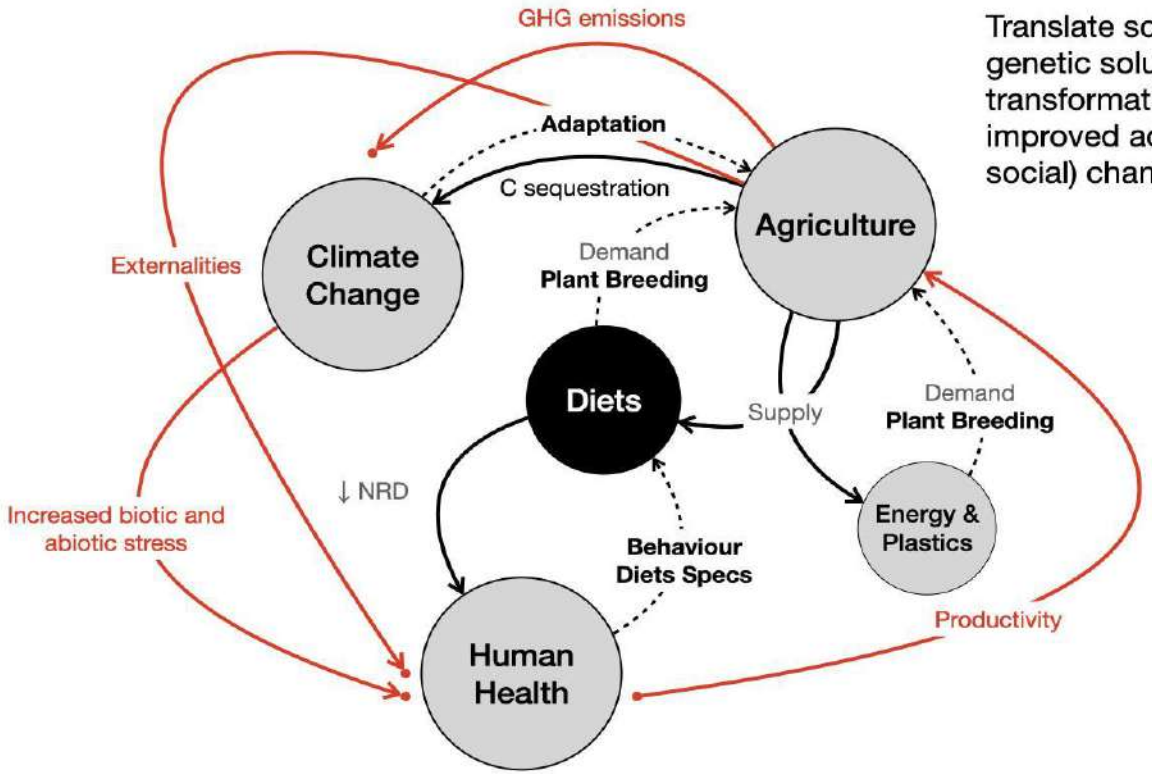


Agriculture produces what humans demand

Changes in Ag will start with change in Diets

Changes in Diets will redefine breeding objectives

What is the role of breeding as a driver of change?



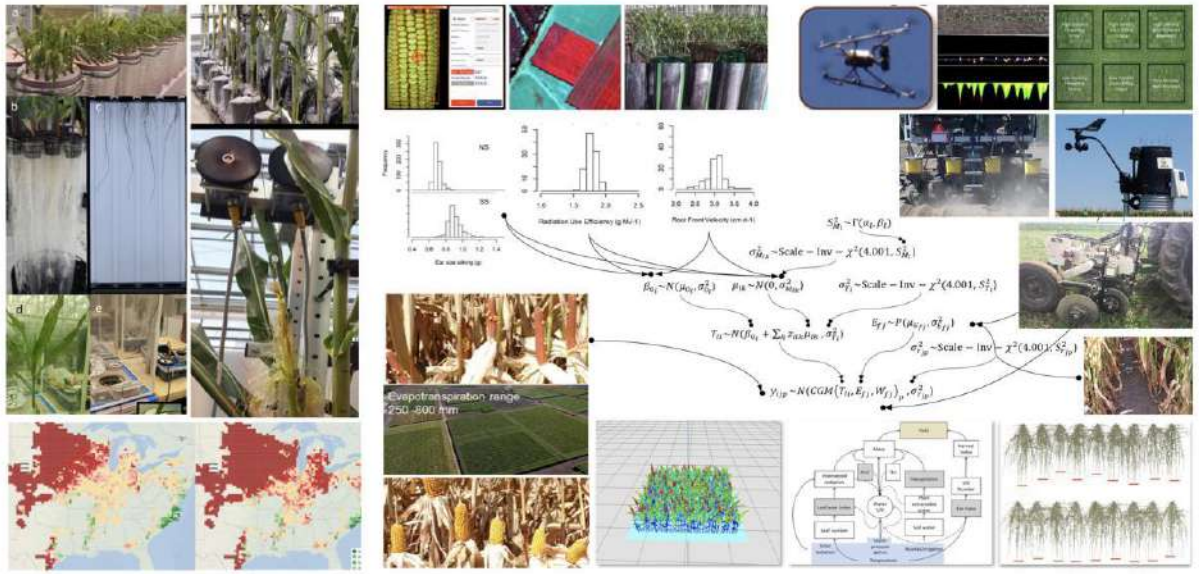
Translate societal demands into genetic solutions to enable the transformation of agriculture for improved adaptation to climate (& social) change

Transition to circular agriculture…

Build upon a proven method

Precision Phenotyping

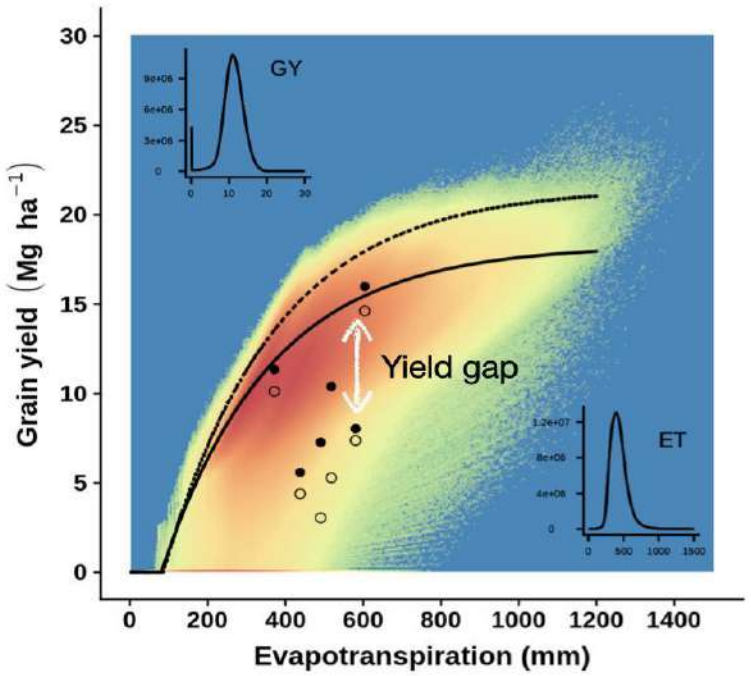
Managed Stress Environments

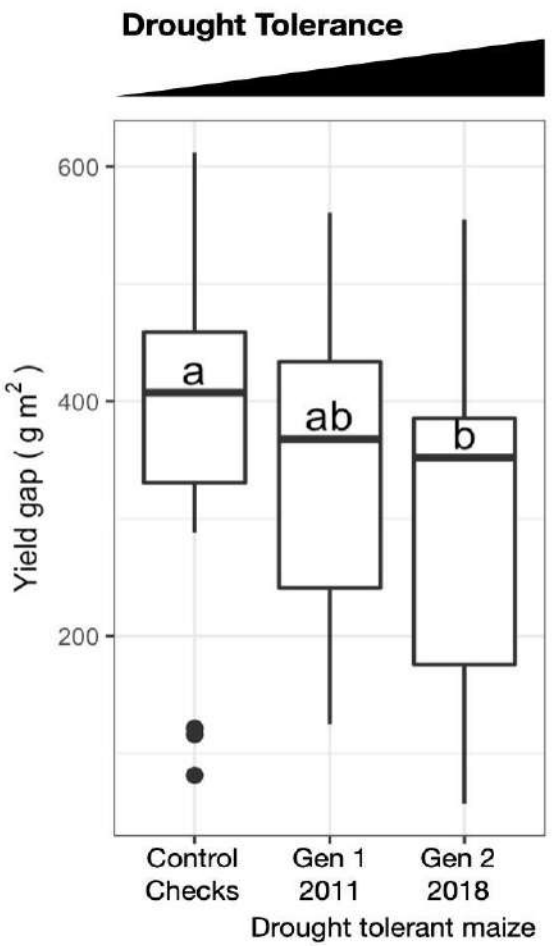


Large scale On Farm evaluations

Crop Model-Whole genome prediction

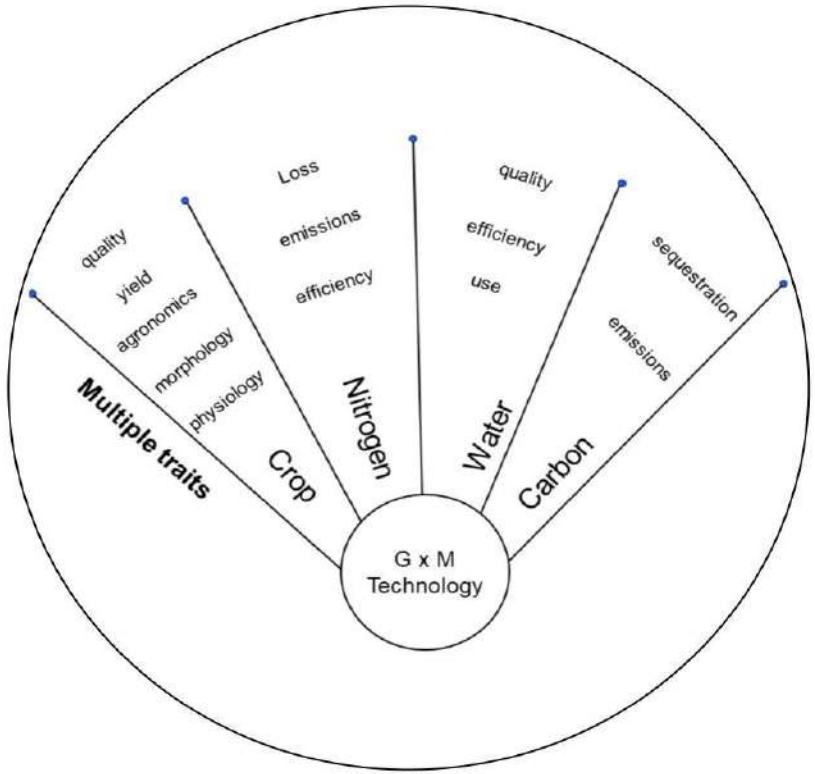
Theory meets evidence





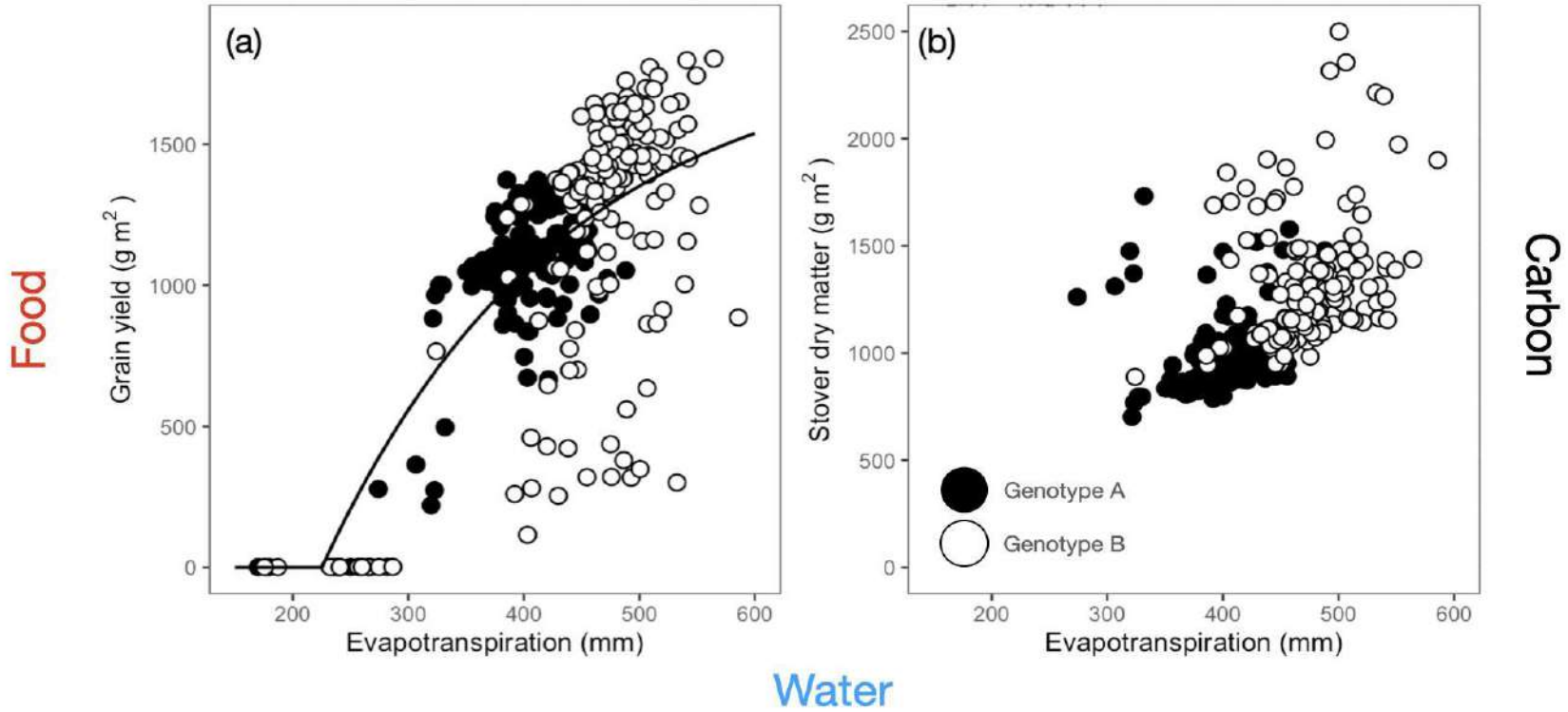
Multidimensional framework

1. Empower decision makers to approach dilemmas
2. Require new prediction methodologies
3. Deal with long-term systems changes (eg, carbon, aquifers)



Prediction in multiple dimensions

More yield and carbon sequestration at the expense of higher water use…
balance C sequestration, externalities and food production



Diepenbrock et al. 2021; Messina et al. 2022.

TOP TAKE-AWAYS

1. Framework for Breeding for Climate Change is lacking
2. Many journeys will be required to adapt to Climate Change
3. Success: Build upon successful breeding technologies

How to adapt sorghum for climate change?
NARS-led breeding networks and many small decisive experiments

Geoff Morris
Associate Professor, Crop Quantitative Genomics, Colorado State University

USAID FROM THE AMERICAN PEOPLE

COLORADO STATE UNIVERSITY

AGRILINKS

Key points:

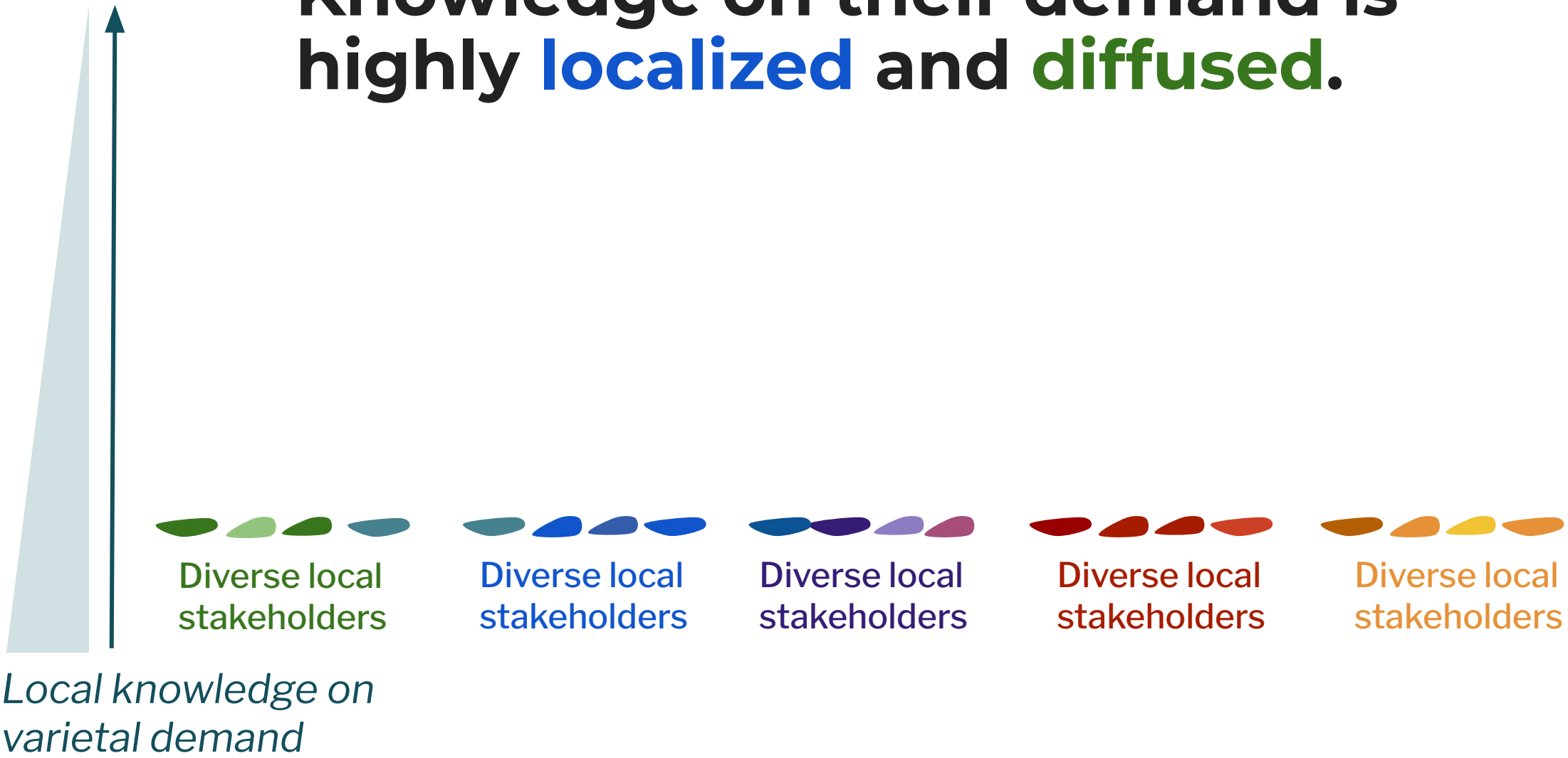
1. NARS-led breeding networks are essential
2. Complex traits require simple approaches

AGRILINKS

What roles for NARS, CG, and IL would best serve smallholders?

Our stakeholders are diverse. Knowledge on their needs and wants (demand) is highly localized and diffused.

Our stakeholders are diverse. Knowledge on their demand is highly localized and diffused.



NARS are in the best position to

(1) understand and aggregate knowledge on local demand and

(2) develop and deliver varieties based on this knowledge

NARS are in the best position to

(1) understand and aggregate knowledge on local demand and

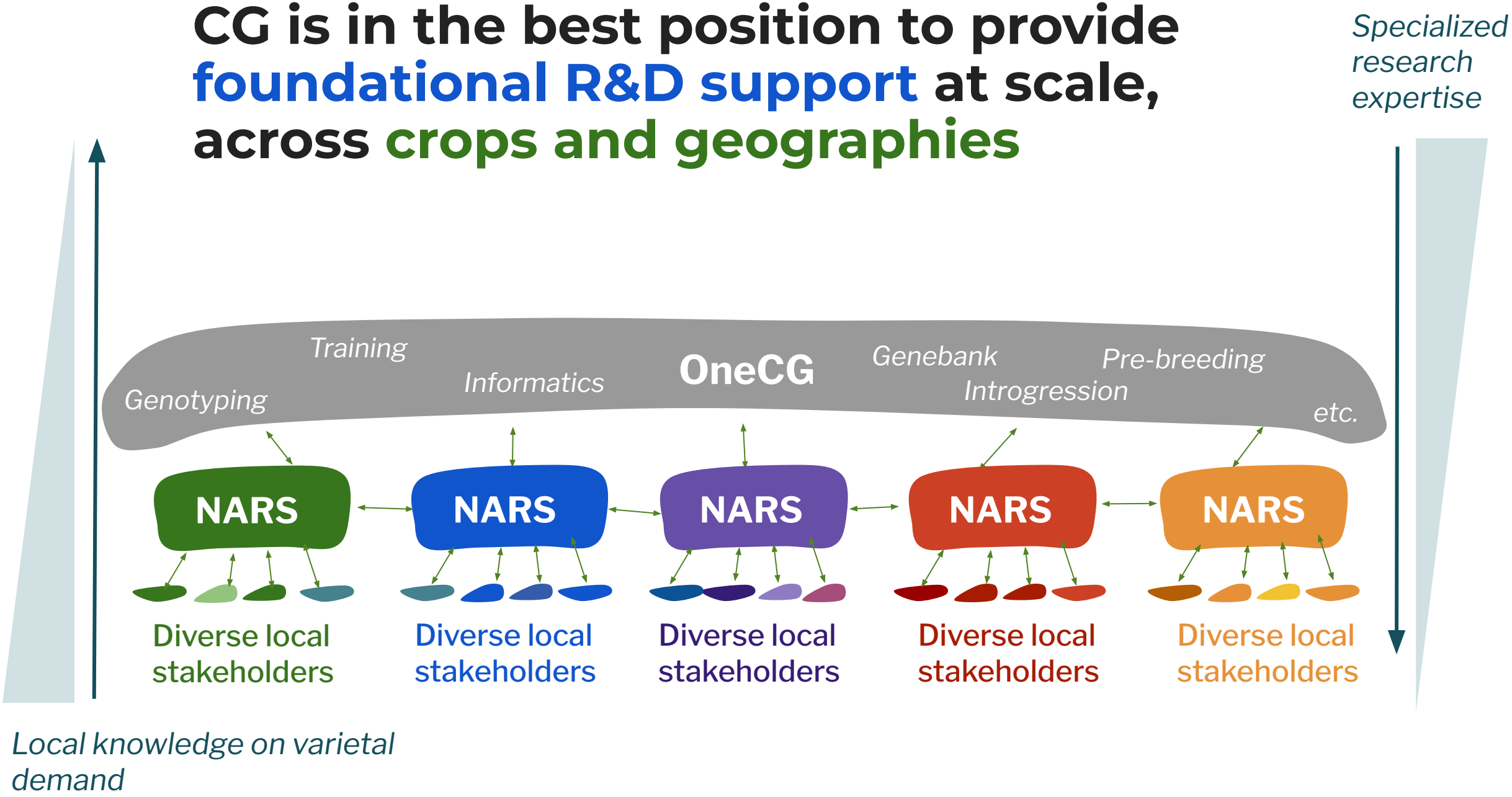
(2) develop and deliver varieties based on this knowledge

Specialized research expertise

Local knowledge on varietal demand

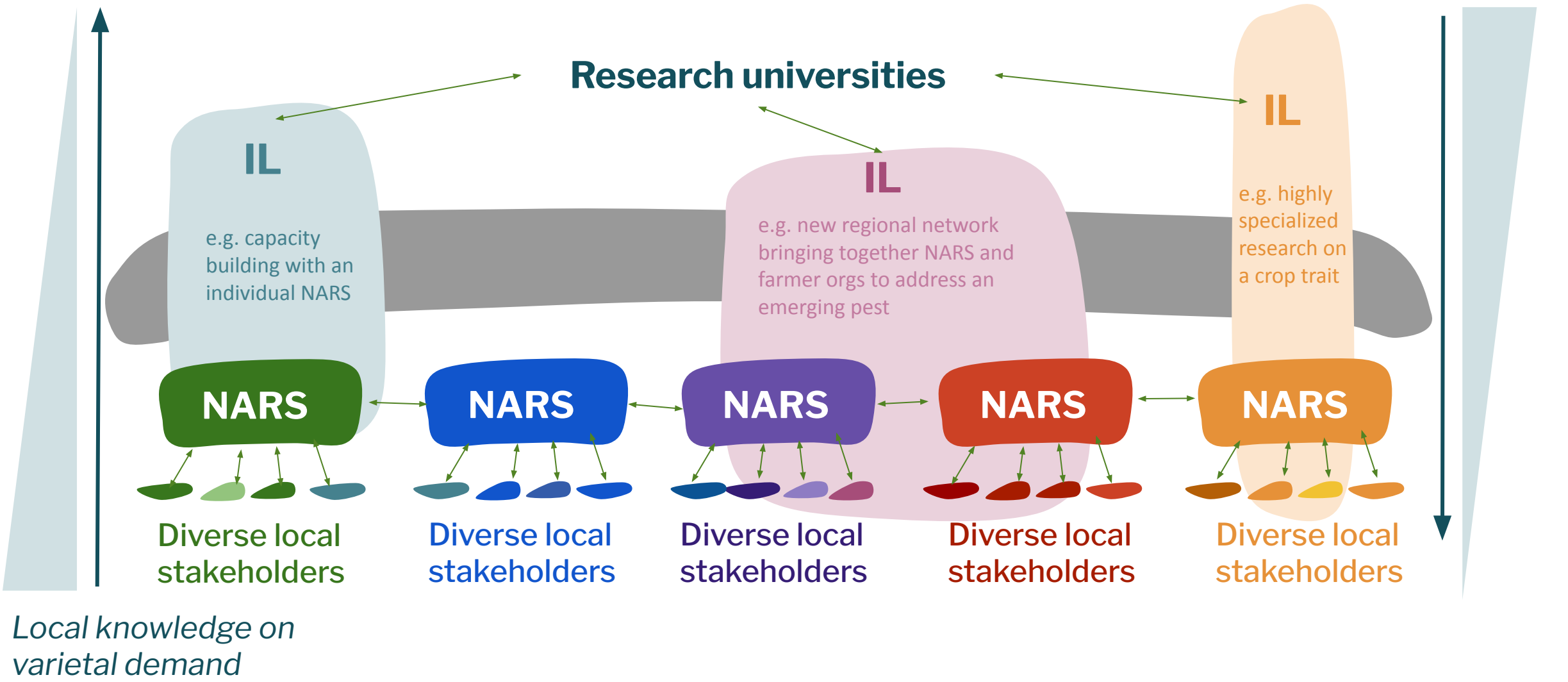
CG is in the best position to provide foundational R&D support at scale, across crops and geographies

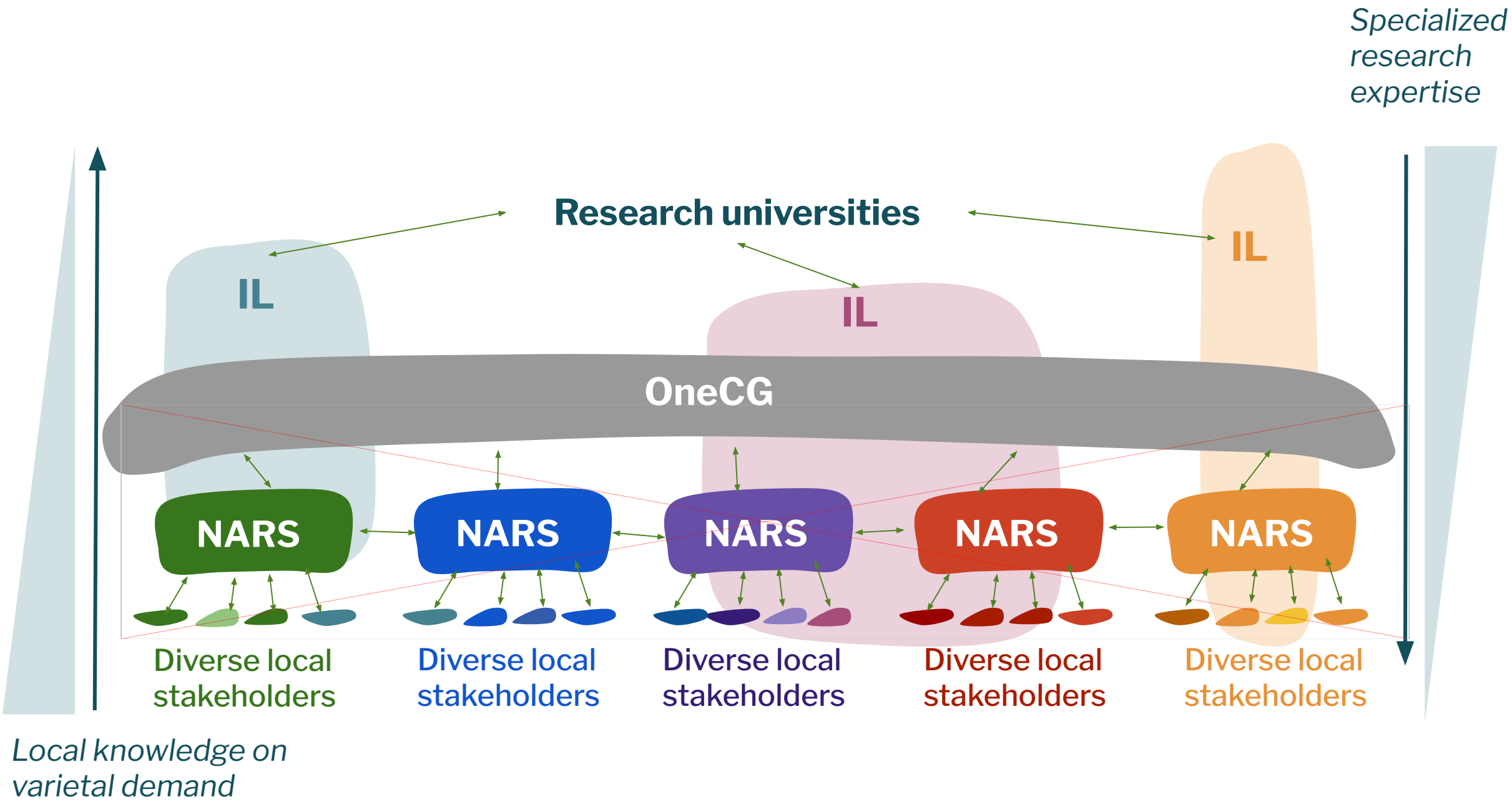
CG is in the best position to provide foundational R&D support at scale, across crops and geographies



ILs are in the best position to provide *specialized* research expertise and *targeted* project funding

ILs are in the best position to provide *specialized* research expertise and *targeted* project funding




Specialized research expertise
Research universities
IL
IL
IL
OneCG
NARS
NARS
NARS
NARS
NARS
Diverse local stakeholders
Diverse local stakeholders
Diverse local stakeholders
Diverse local stakeholders
Diverse local stakeholders
Local knowledge on varietal demand

Key points:

1. NARS-led breeding networks are essential
2. **Complex traits require simple approaches**

AGRILINKS

History of NARS breeding:
Forward pedigree breeding in small populations

Preferred variety

Adapted flowering time

***Striga* susceptibility**

Sufficient forage

Preferred grain quality

Maladapted flowering time

Striga* resistance

Insufficient forage

Unacceptable grain quality

Donor variety

History of NARS breeding:
Forward pedigree breeding in small populations

Preferred variety

Adapted flowering time

***Striga* susceptibility**

Sufficient forage

Preferred grain quality

Maladapted flowering time

Striga* resistance

Insufficient forage

Unacceptable grain quality

Donor variety

New variety

Adapted flowering time

Striga* resistance

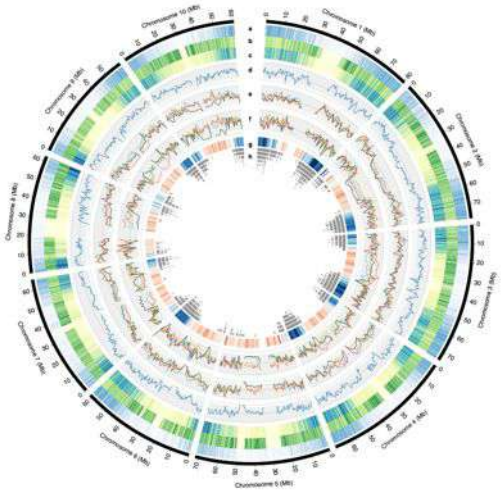
Sufficient forage

Unacceptable grain quality

Limited adoption

Sorghum and millet adoption:
Walker & Alwang 2015

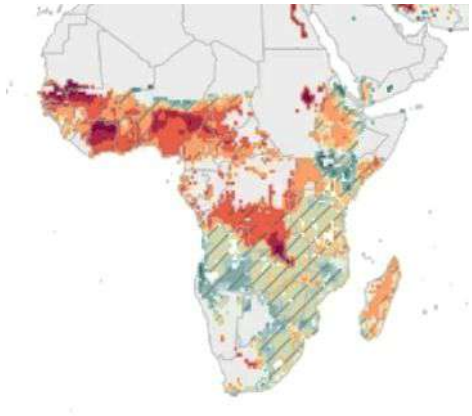
Does NARS breeding for complex traits (e.g. climate adaptation) need complex approaches?



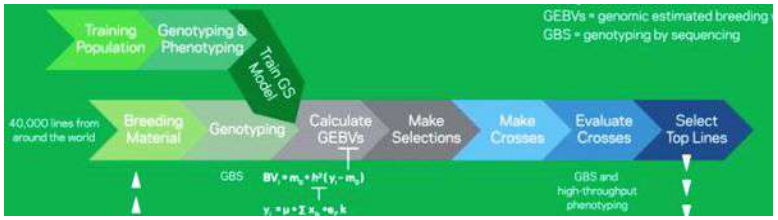
Lozano et al. Nature Plants 2021

Genome sequencing

Climate modeling



Jägermeyr et al. Nature Foods 2021



terraref.org

Genomic selection

Plant Phenomics

terraref.org

Complex traits require simple approaches

- Why did leading seed companies develop and adopt these complex approaches? (genomics, phenomics, modeling)
- Technology that facilitates **many small decisive experiments**
  - Genomic prediction, managed stress trials, or *in silico* experiments
- Wrong lesson: *Transfer technology* that leading seed companies used
- Right lesson: Use the *disciplined problem-solving* approach they applied

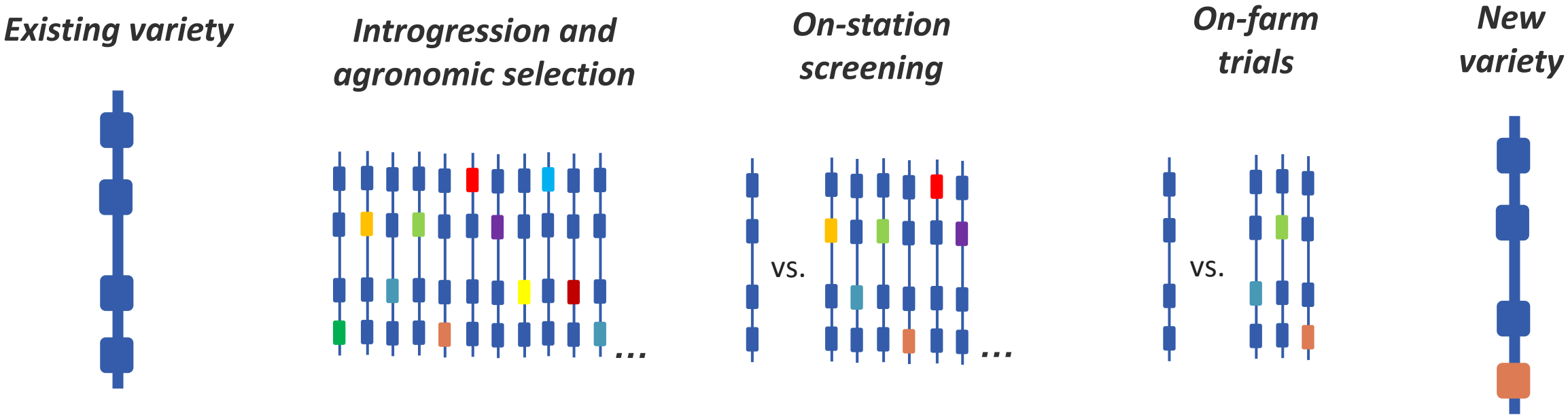
AGRILINKS

What technologies could facilitate *many small decisive* experiments for NARS?

- **Scientific method**
  - Focus on excluding hypotheses as quickly as possible (Platt 1964 *Science*)
- **Breeding fundamentals**
  - Product profiles, seed purity, phenotyping accuracy, etc.
- **Classical genetics**
  - Track major genes, simple markers, test hypotheses using phenotype, etc.
- **Use or adapt whatever new technology is necessary**
  - But only when necessary, and only with hypothesis testing

AGRILINKS

Example: Leveraging introgression lines



(Synthesizing ideas of Jordan et al. 2011 *Crop Science* and Haussmann *et al*. 2012 *JACS*)

- *In conclusion:* How to adapt for climate change from now–2050? Help NARS breeders develop varieties that will be adopted in 2025

AGRILINKS

Gael Pressoir (Université Quisqueya)

Thank You

NARS breeder/researcher collaborators:
Cyril Diatta, Nofou Ouedraogo, Eyanawa Akata, Ardaly Ouesseini, Aissata Mamadou, Ndiaga Cisse, Daniel Fonceka, Jacques Faye, Fanna Maina, Kebede Muleta, Gael Pressoir

USAID Feed the Future and Bill & Melinda Gates Foundation:
Sorghum Millet Innovation Lab (SMIL) & Innovation Lab for Crop Improvement (ILCI)
Sorghum Genomics Toolkit (SGT) & Mining Useful Alleles for Climate Change Adaptation

Geoff.Morris@colostate.edu

www.CropAdaptation.org

AGRILINKS

Scaling of Climate-Smart technologies

A look through the Product Life Cycle Lens

USAID FROM THE AMERICAN PEOPLE

AGRILINKS

What we do

A
brighter future for smallholder farming

AGRISERVICES

INSURANCE

SEEDS2B

RESEARCH & DEVELOPMENT

POLICY

syngenta foundation for sustainable agriculture

AGRILINKS

Elements of our work on Climate Change

- Climate-smart, resilient agriculture (CSRA) is a core component of SFSA's renewed strategic framework, strengthening our ambition to support smallholder farmers to better deal with the consequences of climate change
- SFSA works on a variety of initiatives that support climate-smart farming systems across all its streams
- Delivering and scaling of climate-smart technologies is at the core of our Seeds2B model of variety commercialization
- Catalyzing strategic partnerships along the value chain is key to bring climate-smart technologies to smallholder farmers

syngenta foundation for sustainable agriculture

AGRILINKS

PLC End to end process of variety commercialization

	1 – 2	3	4	5	6	7	8	9	10	11	12
PLC STAGE	Concept & Breeding	Prototype	Early development	Late development	Testing & Registration	Introduction	Growth	Maturity	Decline	Phase out	Out of assortment

AGRILINKS

A deeper dive into the process

Problem Definition		Solution Design		Solution Delivery	
Identify farmers needs	Crop & country scoping	***Design value proposition***	Targeted farmer segment	***Write Launch road map and launch timelines***	Launch road map
	Farmer challenges assessment		Market segmentation/TPP		Launch timeline, including registration
	Value Chain Analysis		Solution statement (hypothesis)	***Create marketing mix: portfolio, price, promotion, place, packaging***	Portfolio Life cycle
	SWOT Context		Economic value analysis for SHF (Farmer ROI), environment and social benefits (solution)		Trial creation and excecution
					Variety performance
					Actual variety profile against TPP
					Value pricing
					Promotional guidelines (branding, packaging, demand creation)
		Draft business models including partnerships	Business model, stakeholder mapping, licensing models		Distribution pathway
				Seed production	Seed production manual (EGS + commercial) Where, how, production recipe
				Legal framework	Legal framework to operate (registration, sales licenses, MTA, MTTA, commercial and licensing agreement)
		High level business case	Investment case: Benefits/cost (NPV and sensitivity analysis)	***Planning process***	**Product Advancement Meeting (PAM)**
					Sales forecast
					Seed Production plan (SPP)

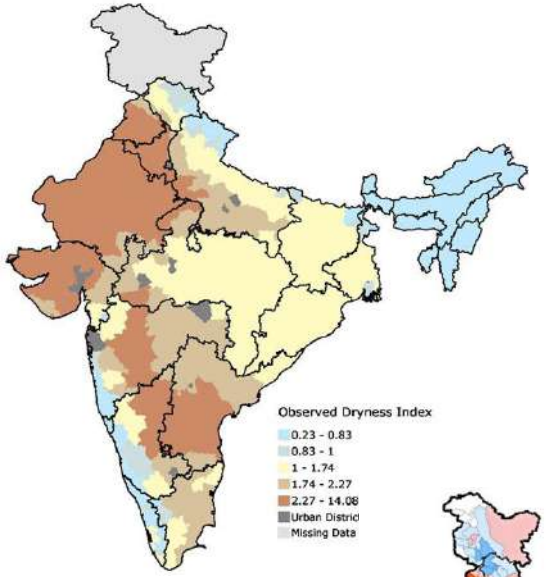
syngenta foundation for sustainable agriculture

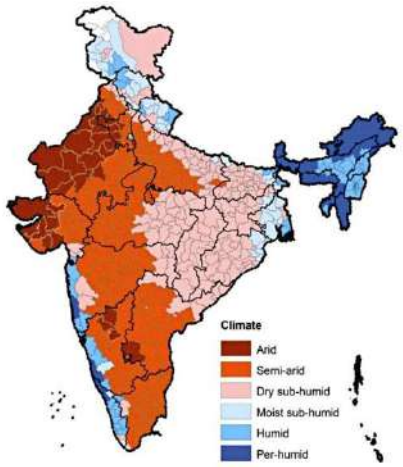
syngenta foundation for sustainable agriculture

Case Example – AAA Maize in India

PROBLEM DEFINITION

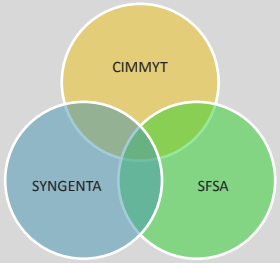
Increasing access for smallholders in semi-arid West Central India to high-yielding, climate smart resilient and affordable maize varieties





SOLUTION DESIGN

AAA hybrid maize – drought tolerant, yielding 2X of OPVs and 80% of popular hybrids and local checks



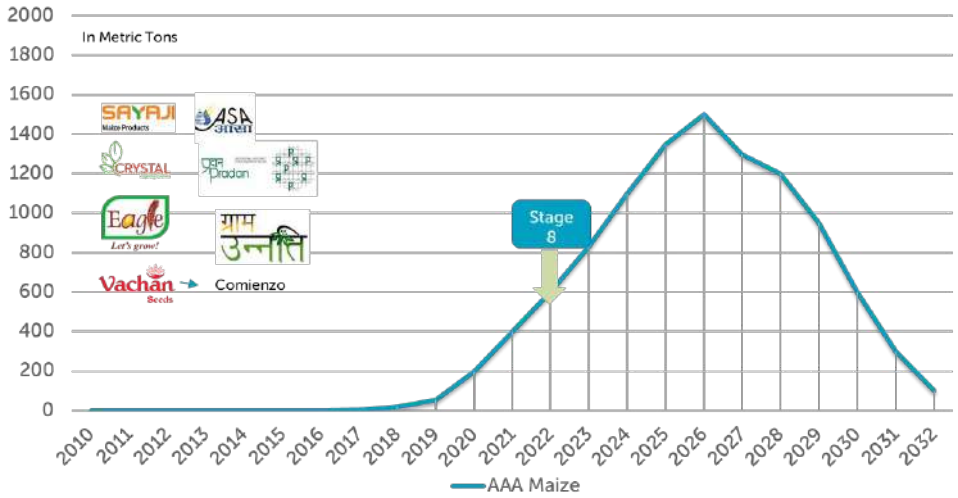
- Market & Product segmentation
- Environmental Benefits
- Social Benefits
- Economic Benefits
- Business Models
- Investment Case

Drought Tolerant | High Yielding | Affordable

AAA maize

SOLUTION DELIVERY

AAA hybrid maize delivered by local SMEs, NGOs and Agri-entrepreneurs: 12,000 farmers grew AAA maize in 2021 Kharif season



syngenta foundation for sustainable agriculture

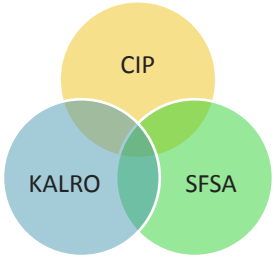
Case Example – Potato in Samburu County - Kenya

PROBLEM DEFINITION

Support crop diversification in Samburu, a primarily pastoral and semi arid area of northern Kenya with recurring drought

SOLUTION DESIGN

Partnership with The International Potato Center, KALRO, and SFSA to trial adapted potato varieties



Altitude	Drought Tolerance	Disease resistance
Maturity	Nematode Resistance	Dormancy

Demonstration of heat-tolerant and early maturing varieties
Wanjiku and *Unica.*

Diversification of economic activities by the introduction of alternative food sources

Expansion of potato growing zones to increase the total production in the country. High productivity with disease free soils .

Demonstration of highly nutritious potato varieties.
Unica is rich in Vitamin C, Iron, and Zinc

SOLUTION DELIVERY

>2,500 farmers adopted potato production in year 1
15 MT tons of EGS produced in Samburu county

Parting Thoughts

- Climate change is one of the most important issues the world must tackle today
- Helping farmers to be able to adapt to these changes and be part of the solution to climate change is at the core of what we **MUST** do

syngenta foundation for sustainable agriculture

AGRILINKS

Thank You

www.syngentafoundation.org

AGRILINKS

Partnership for Climate-Smart Maize in Africa

TELA Maize Project

Mark Edge, Bayer Crop Science

February 10, 2022

USAID FROM THE AMERICAN PEOPLE

AGRILINKS

Key Take Aways

Impact at scale for climate adaptation with climate-smart maize in Africa hinges on three things:

1. Partnerships
2. Products that deliver value and reduce risk for farmers
3. Sustainable holistic seed systems for delivery to the farmer

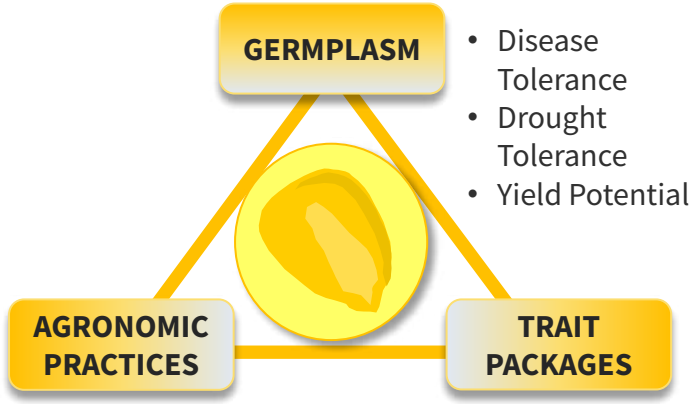
The **TELA® Maize** Project as a case study

Vision & Mission

TELA® Maize Project

Developing *Climate-smart* TELA® Maize Hybrids for African Farmers

To **increase yield stability** and **reduce risk** under drought conditions **through breeding** and **biotech**



- Disease Tolerance
- Drought Tolerance
- Yield Potential

- Farm-level Recommendations

- Insect Control
- Drought Tolerance

AGRILINKS

Public-Private Partnership

TELA® Maize

Framing the partnership – initiated in 2008

TELA™
Stem-borer protected & drought tolerant

Partners	Roles
CIMMYT International Maize and Wheat Improvement Center	**World Leader for breeding maize** for African agro-ecological zones (East and Southern Africa)
AATF	Capacity to access, develop, & deliver **appropriate agricultural technologies** to smallholder African farmers
BAYER	**World Leader in GM crops** **Donated royalty-free:** - Proprietary germplasm - Drought-tolerance trait - Insect-protection (Bt) traits - Regulatory data packages
NARS*	- Expertise in field trials - Breed/Test & release new hybrids - Regulatory approvals

*NARS = National Agricultural Research System

Funded by

USAID FROM THE AMERICAN PEOPLE

BILL & MELINDA GATES foundation

NARS

IIAM

INSTITUTE FOR AGRICULTURAL RESEARCH SAMARU

TARI Transforming Agriculture

የኢትዮጵያ የግብርና ምርምር ኢንስቲትዩት
Ethiopian Institute of Agricultural Research (EIAR)

ARC • LNR Excellence in Research and Development

KALRO

NARO

Countries in scope

AGRILINKS

TELA® Maize Product Concept

- **White Hybrids (Single-cross or 3-way)**
- **25% yield improvement compared to 2008 hybrids under moderate drought conditions**
  - Target 15% from breeding over 10 years
  - **Additional 8–10% from DT transgene**
  - Insect protection from Bt transgene

- **General Product Requirements**
  - Drought tolerance
  - Maturity 125–135 days
  - Disease resistance: GLS, TLB, MSV and **MLN**
  - Agronomic traits: root-lodging, prolificacy, maturity, husk cover
- **Consumer Requirements**
  - Maintain required milling quality
  - Maintain meal yield
  - Grain Texture : flint to flinty-dent

TELA™
Stem-borer protected & drought tolerant

AGRILINKS

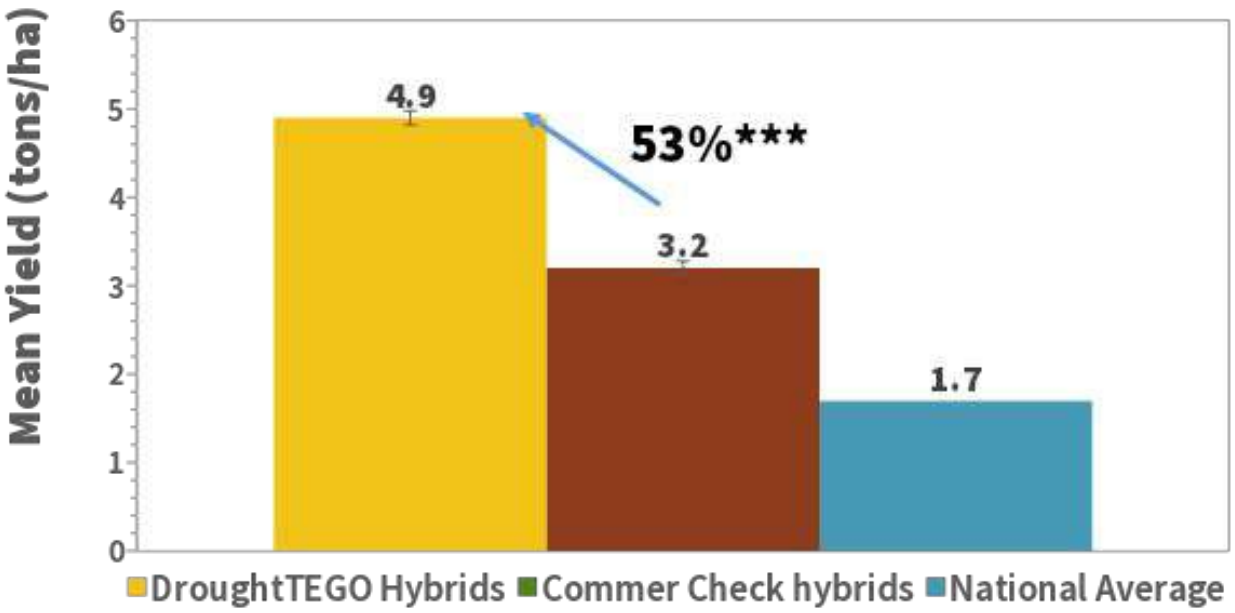
Success Story

DroughtTEGO®

Hybrids Mean Yield Across Locations and Seasons; Kenya

(2015LR, 2015SR, 2016 LR, 2016SR & 2017 LR)

TEGO hybrids are conventional (non-GM) with **improved drought tolerance**



Source: Obunyali *et al*. 2019. Agronomy Journal. 111: 1–15

Drought TEGO™
Innovation and protection for a better harvest

BRANDING GUIDELINES

Seed Pack

AGRILINKS

TELA® Maize – Current Phase (2018 - 2023): Primary Goal and Key Components

TELA™
Stem-borer protected & drought tolerant

Primary Goal:

Secure **Approvals** and Initiate **Products Commercialization**

*In at least **4 African countries** by 2023*

GM Status in Africa:

- No commercial GM maize approved for sale yet in **Sub-Sahara Africa** (ex RSA)
- Bt Cotton (**Kenya, Malawi & Nigeria**) and Bt Cowpea (**Nigeria**) are in the market
- **Nigeria** approved Bt Maize but it will require 1 season for variety registration
- TELA Maize project is leading the way for GM maize approvals in **SSA**

Approval and Commercialization Process:

1
Development, submission of dossier and management of review process

2
Advocacy, outreach and communications

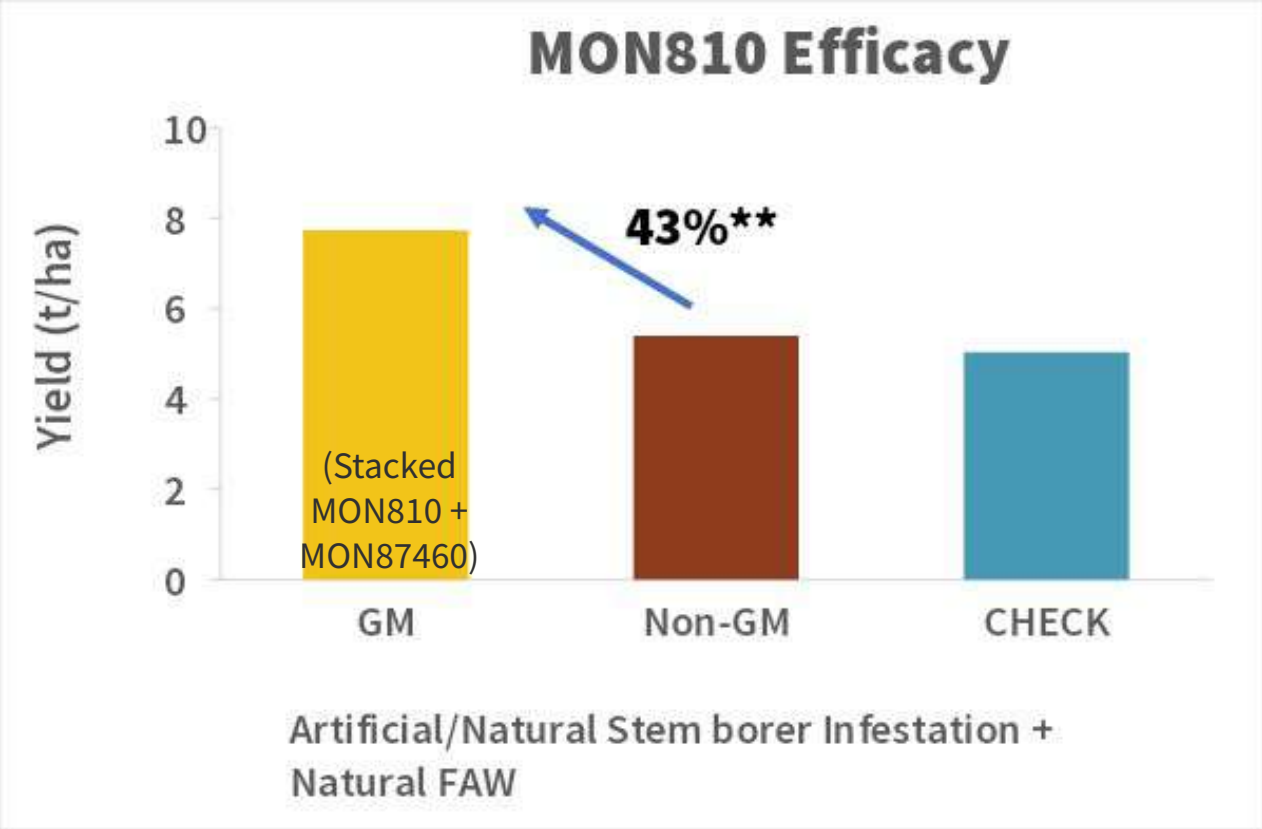
3
Testing and approval of compelling products

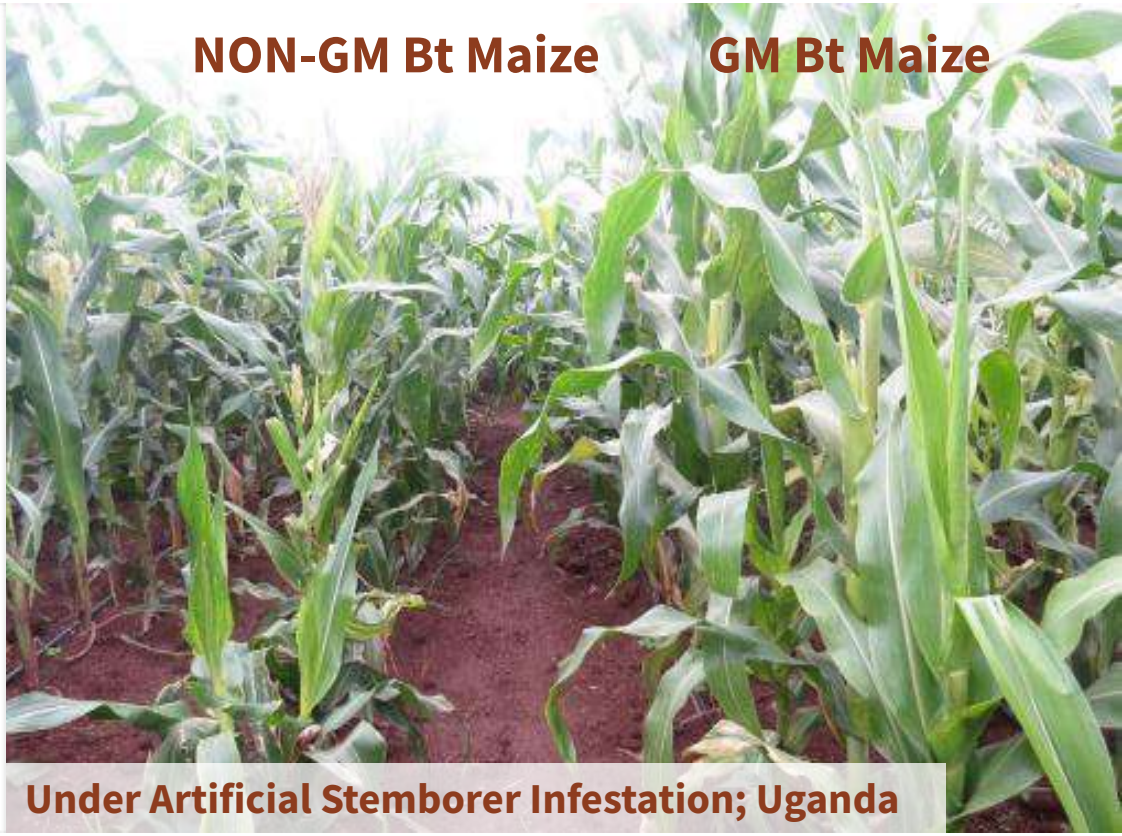
4
Commercialization and deployment

AGRILINKS

Efficacy of GM* vs Non-GM Hybrids

(2016–2020; 6 Locations – 12 CFTs: KE, UG, TZ, MZ, and ET)





*GM = Genetically Modified

Why TELA Works

Builds on Core Strengths

Common Objectives

Focused on specific outcomes

Long-term commitments by partners & donors

Challenges Remaining

BIOTECH APPROVALS

SEED COMPANY SCALING

QUALITY SEED PRODUCTION

FARMER AWARENESS

STEWARDSHIP

GEOGRAPHICAL EXPANSION

Thank You!

Mark Edge

Director of Partnerships, Seeds & Traits Development for LMICs

Email: mark.edge@bayer.com

AGRILINKS

Q&A

AGRILINKS

Thank you!

AGRILINKS